PRICE: $5.00

Model CC 15—1.5M

Serial No. . . . . .

INSTRUCTION MANUAL

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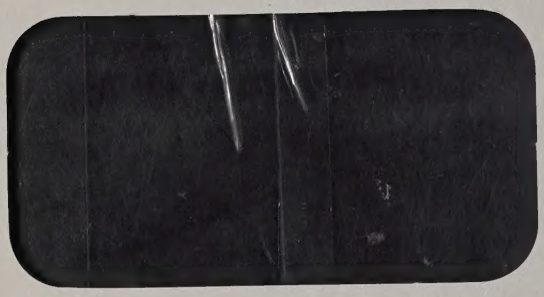

KEPCO

CC

design group

CONSTANT
CURRENT
POWER SUPPLY

Model CC 15—1.5M

Serial No. .....

INSTRUCTION MANUAL

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TABLE OF CONTENTS

PARAGRAPH		PAGE
	SECTION I – INTRODUCTION	
1-1	Scope of Manual	1-1
1-3	General Description	1-1
1-9	Accessories	1-1
1-11	Specifications, General	1-2
1-12	Specifications, Performance	1-2
1-13	Specifications, Physical	1-3
	SECTION II – INSTALLATION	
2-1	Unpacking and Inspection	2-1
2-3	Terminations	2-1
2-4	A-C Power Requirements	2-1
2-7	A-C Grounding	2-2
2-9	D-C (Signal) Grounding and Islolation	2-3/2-4
2-11	Preliminary Check-Out Procedure	2-3/2-4
2-13	Installation	2-3/2-4
2-15	Cooling	2-3/2-4
	SECTION III – OPERATION	
3-1	Operating Considerations	3-1
3-5	Standard Operation, Local Control	3-2
3-10	Introduction to Remote Programming	3-3
3-15	Adjustments for Precision Programming Ratio	3-4
3-18	Remote Resistance Programming	3-4
3-23	Remote Programming by a Control Voltage	3-5
3-30	Extension of the Power Supply Range	3-8
	SECTION IV – THEORY OF OPERATION	
4-1	General	4-1
4-3	Simplified Diagram Discussion	4-1
4-6	Detailed Circuit Description	4-2
	SECTION V – MAINTENANCE	
5-1	General	5-1
5-3	Disassembly	5-1
5-5	Internal Adjustments	5-2
5-7	A-C Stability Adjustment	5-2
5-11	Overcurrent Adjustment	5-2
5-14	Trouble Shooting	5-2
5-17	Performance Measurements	5-3
5-19	D-C Measurements	5-3
	SECTION VI – PARTS LIST AND DIAGRAMS	
6-1	General	6-1/6-2
6-3	Ordering Information	6-1/6-2

LIST OF ILLUSTRATIONS

FIGURE		PAGE
1-1	Kepco CC Current Stabilizer Typical (Uncased) Module	-iii-
1-2	Accessories, Kepco Plug-in Modules	-iv-
1-3	Mechanical Outline Drawing, CC Design Group	1-4
2-1	Conversion to 230V A-C Source Operation and Location of Internal Adjustments	2-1
2-2	Rear Terminations, CC Group	2-2
2-3	Terminations and Controls, Front Panel	2-2
3-1	Comparison, Voltage vs. Current Stabilizer	3-1
3-2	Rear Connections for Standard Operation	3-2
3-3	The Current Stabilizer Model	3-3
3-4	Programming Ratio Adjustment (Standard)	3-4
3-5	Resistance Programming	3-5
3-6	Remote Output Current Control by Voltage	3-6
3-7	Sine Wave Programming, (Waveforms)	3-6
3-8	Connections for Sine Wave Programming	3-7
3-9	Connections for D-C Voltage Programming	3-8
3-10	Automatic Parallel Connection	3-9
3-11	Master/Slave Parallel Connection	3-9
3-12	Simplified Connection Diagram, CC Module	3-10/3-11
4-1	Simplified Diagram	4-1
5-1	Disassembly	5-1
5-2	Test Set-Up for Output Effect Measurements	5-4
6-1	Chassis Component Location	6-9/6-10
6-2	PCB #1 (A1) Component Location	6-11/6-12
6-3	Main Schematic	6-13/6-14

LIST OF TABLES

TABLE		PAGE
1-1	D-C Output and A-C Input, CC Group	1-2
1-2	Output Effects	1-3
2-1	Internal Controls	2-1
2-2	Terminations and Controls, Front Panel	2-2
3-1	Load Ranges, CC Group	3-1

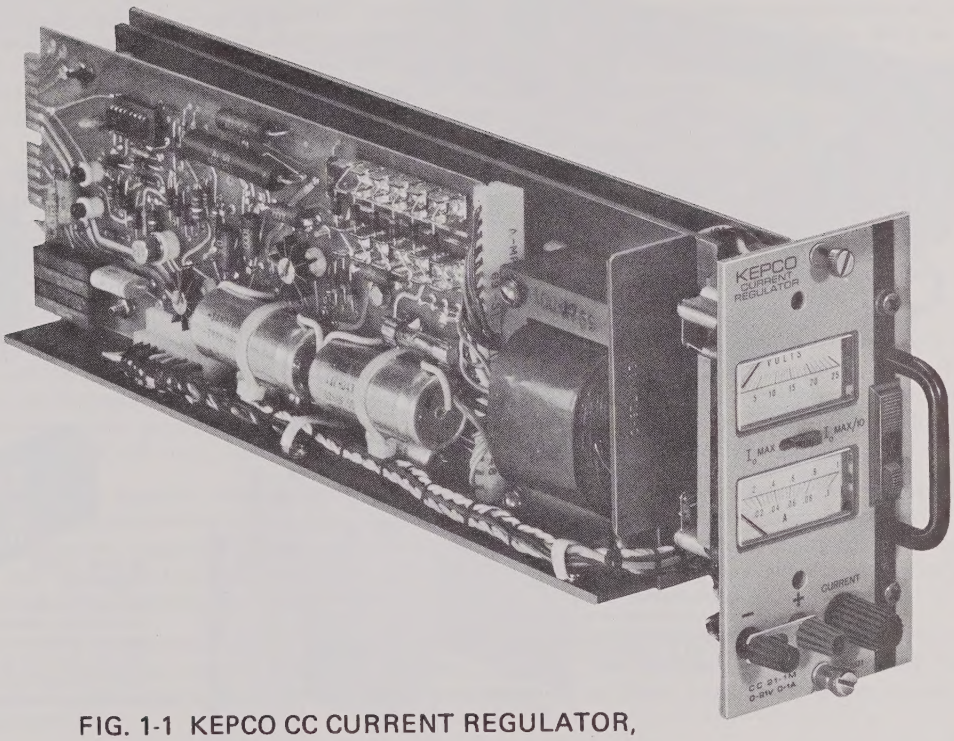
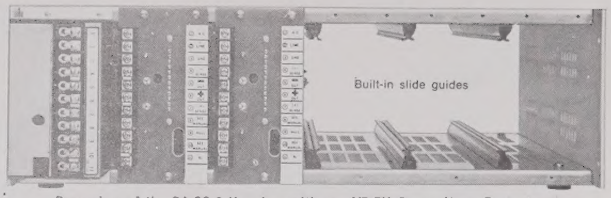


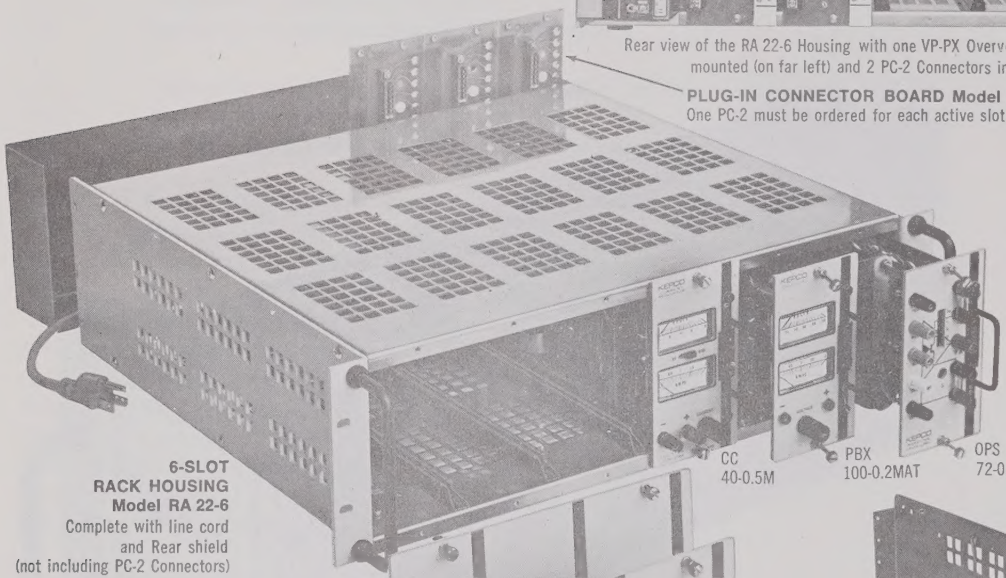
FIG. 1-1 KEPCO CC CURRENT REGULATOR,
TYPICAL (UNCASED) MODULE

FIG. 1-2 KEPCO ACCESSORIES FOR PLUG-IN MODULES

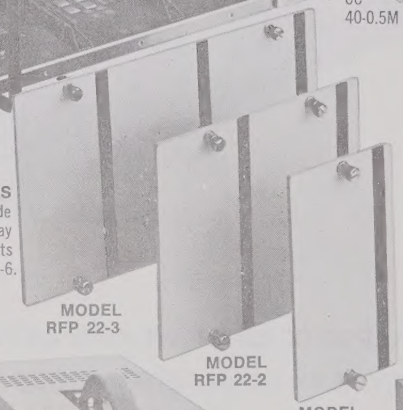


Rear view of the RA 22-6 Housing with one VP-PX Overvoltage Protector mounted (on far left) and 2 PC-2 Connectors installed

PLUG-IN CONNECTOR BOARD Model PC-2
One PC-2 must be ordered for each active slot in the RA 22-6.



6-SLOT RACK HOUSING Model RA 22-6
Complete with line cord and Rear shield (not including PC-2 Connectors)

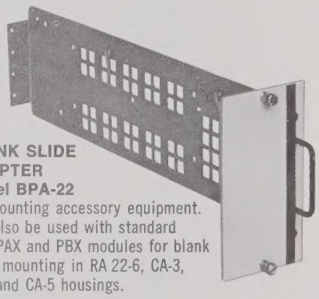


FILLER PANELS
(supplied without slide assembly and handle), may be used to fill unused slots in CA-3, CA-4, CA-5 and RA 22-6.

MODEL RFP 22-3

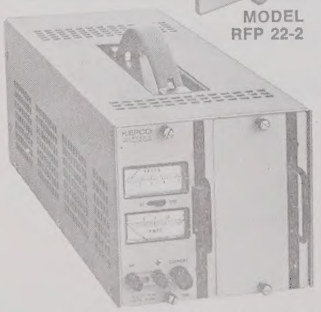
MODEL RFP 22-2

MODEL RFP 22-1



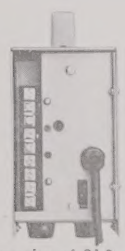
BLANK SLIDE ADAPTER Model BPA-22
For mounting accessory equipment. May also be used with standard OPS, PAX and PBX modules for blank panel mounting in RA 22-6, CA-3, CA-4 and CA-5 housings.

SINGLE UNIT HOUSING Model CA-3
Supplied complete with a built-in PC-2 connector.

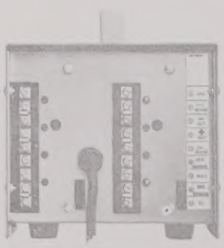


DOUBLE UNIT HOUSING Model CA-4
Supplied complete with a built-in dual PC-2 connector.

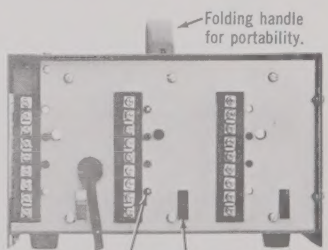
TRIPLE UNIT HOUSING Model CA-5
Supplied complete with a triple PC-2 connector.



Typical rear view of CA-3, showing access terminals and connector.



Typical rear view of CA-4, showing integral connector (Double PC-2) supplied.



Typical rear view of CA-5, showing coding pins, connectors and line cord.

Slot provides access to internal adjustments in mounted supplies.

SECTION I – INTRODUCTION

1-1 SCOPE OF MANUAL

1-2 This manual contains instructions for the installation, operation and maintenance of the Kepco CC Group of CURRENT STABILIZERS.

1-3 GENERAL DESCRIPTION (Refer to FIG. 1-1)

1-4 The KEPCO CC GROUP of Current Stabilizers consists of a series of quick-recovery, current stabilized power supplies, able to respond to load changes at rates up to 2 microseconds per volt. Specifically designed as a CURRENT SOURCE, the power supplies in the this group overcome successfully the disadvantages usually associated with standard ***voltage*** stabilizers converted to supply stabilized ***current:***

a) In the CC, no shunt output capacity interferes with fast recovery from load voltage changes.

b) In the CC, no parallel loading of the output by conventional metering takes place, since a special integrated circuit, high impedance interface between the output and the metering is used.

c) External sensing resistors or controls are not needed. Linear, high-resolution front panel control of the output current is provided. Sensing resistors, optimized for two output ranges, and selected for low temperature coefficient are built-in.

d) No external offset adjustment required. The CC features special offset circuitry permitting operation from zero to the maximum rated output current.

1-5 The CC group of power supplies are as close to the model of an ideal current source as the state of the art permits. An impressive example of the superiority of the CC as a current stabilizer over a conventional voltage/current stabilized supply may be made by comparing their respective recovery times for load changes. Conventional power supplies, operating in a current mode will be delayed by their output filtering to approximately 2×10^2 V/sec., while the capacitorless CC will respond with 0.5×10^6 V/sec.

1-6 Specifications and electrical characteristics of all models in the design group are identical, except as noted in Table 1-1. All models are front panel equipped with: two recessed meters, a combination on-off switch and pilot light assembly, output terminals (with shorting-link) and a 10-turn current control, affording full output control over two output ranges. Ranges are switched on a 1:10 range switch which simultaneously switches the ammeter for full scale readout on both ranges.

1-7 The CC module is terminated at the rear with a printed circuit board connector. Convenient connections for a-c input, d-c output and remote programming are thus provided. The modular construction of the CC series makes these units equally suitable for either case-mounting or rack installations (refer to par. 1-9, "Accessories").

1-8 The power supplies of the CC design group are constructed on a steel frame with the aluminum main chassis and the front panel attached to the frame. Stainless steel guide pins (removable for case installation) are provided for rack-mounting.

1-9 ACCESSORIES (Optional, not supplied. Refer to FIG. 1-2)

1-10 Kepco CC modules are supplied without an a-c line cord. A-C power input and/or programming connections must therefore be made via the printed circuit board mating connector or using one of the listed accessories.

a) MATING CONNECTOR for uncased operation: KEPCO Model PC-1 or METHODE Model CD-612-S-P7.

b) SINGLE-SLOT HOUSING accepts single CC module and provides all necessary rear terminations, KEPCO Model CA-3 (a-c line cord included).

c) DOUBLE-SLOT HOUSING, KEPCO Model CA-4, accepts two CC modules or mixture,* rear terminations provided, (a-c line cord included).

d) TRIPLE-SLOT HOUSING, KEPCO Model CA-5, accepts three CC modules or mixture,* rear terminations provided, (a-c line cord included).

e) RACK CABINET, KEPCO Model RA 22–6, accepts six CC modules or mixture,* each mounted unit needs a plug-in adaptor (f), (a-c line cord included).

f) PLUG-IN ADAPTOR, KEPCO Model PC–2, required for rack-mounting each plug-in module.

***NOTE:** Multiple-slot housings will accept a mixture of KEPCO modular units (OPS–TA, PBX–MAT), as well as blank-panel inserts such as BPA and RFP.

g) RACK MOUNT, KEPCO MODEL RA–32, accepts up to three CC modules, or mixture, together with two 1/4 width or one 1/2 width power supply of the type that usually mount in RA–24.

h) FILLER PANELS

1) KEPCO Model RFP 22–1 to cover (1) empty slot in rack cabinet (RA 22–6), or one of the multiple slot housings (CA–4, CA–5), or one of the 1/6th slots in RA–32.

2) KEPCO Model RFP 22–2 to cover (2) empty slots.

3) KEPCO Model RFP 22–3 to cover (3) empty slots.

1-11 SPECIFICATIONS, GENERAL

a) A-C INPUT: 105V to 125V a-c or 210V to 250V a-c (selectable), 50 to 440 Hz, single phase. Input current: Refer to Table 1-1.

b) AMBIENT OPERATING TEMPERATURE: −20°C to +65°C.

c) STORAGE TEMPERATURE: −40°C to +85°C.

d) ISOLATION: 500 volts maximum (d-c or p-p) may be connected from chassis to either output terminal.

1-12 SPECIFICATIONS, PERFORMANCE

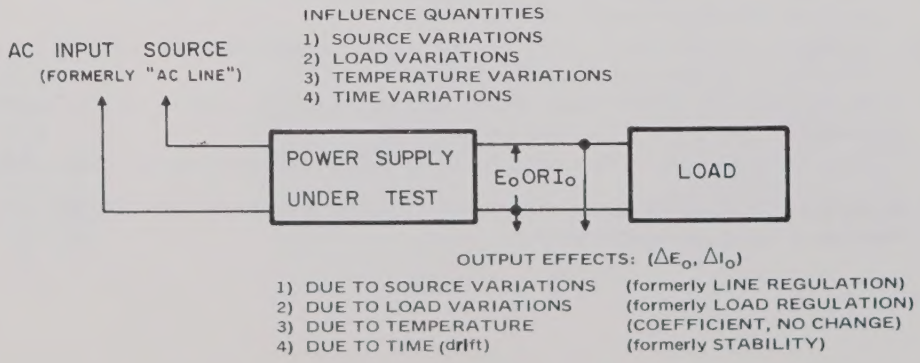
a) D-C OUTPUT: Refer to Tables 1-1 and 1-2.

MODEL	D-C OUTPUT		OUTPUT IMPEDANCE OHMS MINIMUM + SHUNT CAPACITY IN μF	A-C INPUT CURRENT (AT 125V A-C LINE)
	CURRENT	VOLTAGE		
CC 7–2M	0–2A	0–7V	70K +0.2	0.6A
CC 15–1.5M	0–1.5A	0–15V	200K +0.1	0.65A
CC 21–1M	0–1A	0–21V	400K +0.1	0.6A
CC 40–0.5M	0–0.5A	0–40V	1.6M +0.1	0.5A
CC 72–0.3M	0–0.3A	0–72V	4.8M +0.1	0.5A
CC 100–0.2M	0–0.2A	0–100V	10M +0.1	0.5A

TABLE 1-1 D-C OUTPUT AND A-C INPUT, CC GROUP.

NOTE: Kepco has adopted new technical terms recommended by the International Electrotechnical Commission (IEC). These terms replace or supplement previously used expressions, mainly to avoid difficulties in translation and prevent erroneous interpertations at home and abroad.

In this instruction manual Kepco discontinued the use of the specifications entitled "line regulation" and "load regulation" because of the long standing (and misleading) connotation that a power supply regulated the line of the load, instead, Kepco will follow the recommendation of the IEC and speak of the "Output Effects, caused by changes in the influence Quantities." The "Output Effects" are specified either as a percentage change referred to the maximum specified output voltage (E_o) or current (I_o) or as an absolute change (ΔE_o, ΔI_o) directly in millvolts or milliamperes or both. The "Influence Quantities" are the "Source Variations" (formerly a-c line variations), the changes in load, temperature or time as previously specified. The illustration below will clarify the use of the new terminology.


INFLUENCE QUANTITIES
1) SOURCE VARIATIONS
2) LOAD VARIATIONS
3) TEMPERATURE VARIATIONS
4) TIME VARIATIONS
AC INPUT SOURCE
(FORMERLY "AC LINE")
POWER SUPPLY UNDER TEST
Eo OR Io
LOAD
OUTPUT EFFECTS: (ΔEo, ΔIo)
1) DUE TO SOURCE VARIATIONS (formerly LINE REGULATION)
2) DUE TO LOAD VARIATIONS (formerly LOAD REGULATION)
3) DUE TO TEMPERATURE (COEFFICIENT, NO CHANGE)
4) DUE TO TIME (drift) (formerly STABILITY)

VARIATIONS IN INFLUENCE QUANTITY (Δ)		OUTPUT EFFECTS
ΔA-C INPUT SOURCE:	105 to 125V a-c or 210 to 250V a-c	<0.0005% or 0.2 μA*
ΔLOAD:	No load to full load	<0.005% or 2μA*
ΔTIME:	8 hours (drift)	<0.02% of selected full scale range
ΔTEMPERATURE:	Per °C	<0.01% of selected full scale range

*Whichever is greater.

TABLE 1-2 OUTPUT EFFECTS.

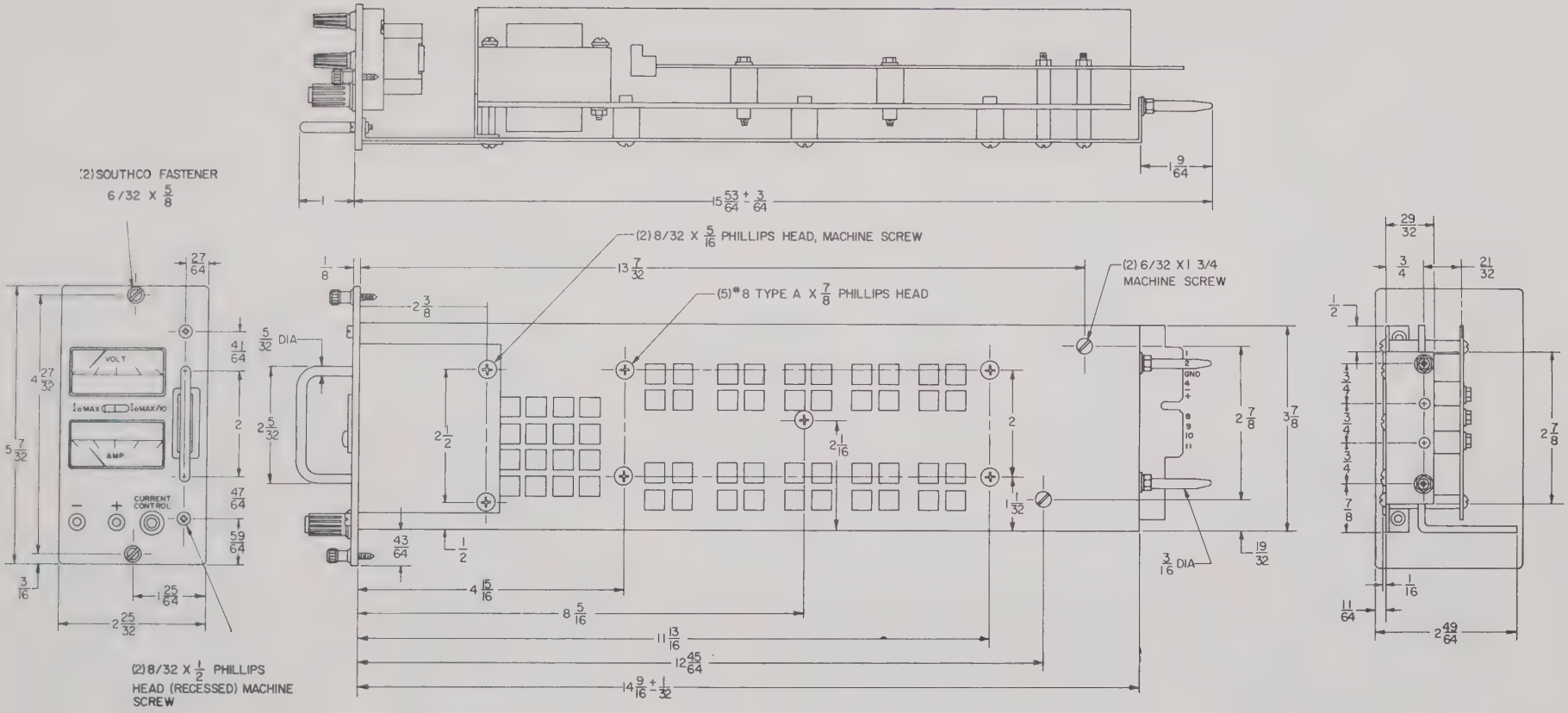
NOTE: While measurements of output effects due to variations in any one influence quantity are performed, variations in all other influences are held constant. This tabulation specifies the maximum change in the stabilized output for each variation of the listed influence quantities. For a "worst case" analysis of the equipment behavior in a given environment, the output effects for each anticipated influence variation must be summed.

b) OUTPUT RIPPLE: Less than 0.02% of the maximum rated output current (high or low range), true rms, at any operating condition.

c) CURRENT RECOVERY (from step load voltage): Output current will return to the specified regulation band within 2 μsec. per volt compliance. (Model CC 7–2M: 4 μsec. per volt.)

1-13 SPECIFICATIONS, PHYSICAL

a) Refer to FIG. 1-3, "Mechanical Outline Drawing," for dimensions, materials used and finish.


(2) SOUTHCO FASTENER 6/32 X 5/8
(2) 8/32 X 5/16 PHILLIPS HEAD, MACHINE SCREW
(5) #8 TYPE A X 7/8 PHILLIPS HEAD
(2) 6/32 X 1 3/4 MACHINE SCREW
VOLT
AMP
CURRENT CONTROL
(2) 8/32 X 1/2 PHILLIPS HEAD (RECESSED) MACHINE SCREW
GND
3/16 DIA
5/32 DIA

NOTES:

1. THIS DRAWING IS USED FOR MODELS: CC 7-2M, CC 15-1.5M, CC 21-1M, CC 40-0.5M, CC 72-0.3M AND CC 100-0.2M
2. MAT'L: CHASSIS, 16 GAUGE COLD ROLLED STEEL, FRONT PANEL 1/8 THICK ALUM.
3. FINISH: CHASSIS, CADMIUM PLATE WITH A CRONAK WASH
   FRONT PANEL, LIGHT GRAY PER FEDERAL STD. 595 COLOR No. 26440
4. REFER TO KEPCO CATALOG FOR DETAILED SPECIFICATIONS

FIG. 1-3 MECHANICAL OUTLINE DRAWING, CC-DESIGN GROUP

SECTION II – INSTALLATION

2-1 UNPACKING AND INSPECTION

2-2 This instrument has been thoroughly inspected and tested prior to packing and is ready for operation. After careful unpacking, inspect for shipping damage before attempting to operate. Perform the preliminary operational check as outlined in paragraph 2-11 below. If any indication of damage is found, an immediate claim with the responsible transport service must be entered.

2-3 TERMINATIONS

a) FRONT PANEL: Refer to FIG. 2-3 and TABLE 2-2.

b) REAR: Refer to FIG. 2-2.

c) INTERNAL ADJUSTMENTS: Refer to TABLE 2-1 and FIG. 2-1.

REFERENCE DESIGNATION	ADJUSTMENT	PURPOSE	ADJUSTMENT PROCEDURE
R15	I_o MAXIMUM	OVERLOAD CURRENT CONTROL	PAR. 5-11
R18	E_{io} NULL	ZERO CURRENT CONTROL	PAR. 3-17
R19	LAG NETWORK	A-C STABILITY CONTROL	PAR. 5-7
R23	I_b ADJUST	CONTROL CURRENT CALIBRATION	PAR. 3-17

TABLE 2-1 INTERNAL CONTROLS.

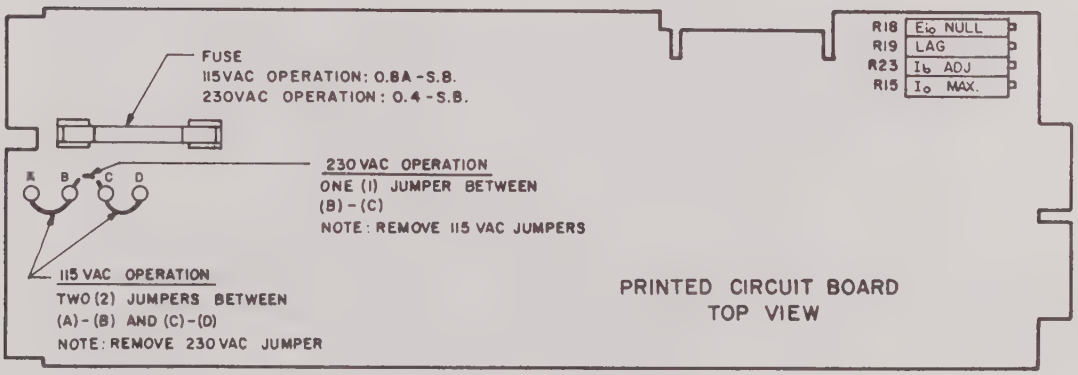


FIG. 2-1 LOCATION OF SOURCE SELECTOR AND INTERNAL ADJUSTMENTS.

2-4 A-C POWER REQUIREMENTS

2-5 CC Current Stabilizers are normally delivered for operation on a single phase, 105 to 125V a-c input source, 50 to 440 Hz. For operation on 210 to 250V a-c input sources, the jumper connections for the main transformer (T201) must be changed as shown in FIG. 2-1.

2-6 PROCEDURE FOR CONVERSION TO 230V A-C INPUT SOURCE OPERATION

a) Disconnect power supply from a-c input source.

b) Remove bare wire jumpers between terminals (A) and (B) as well as (C) and (D).

c) Connect bare wire jumper between jumper terminals (B) and (C).

d) Insert correct fuse value. (See FIG. 2-1.)

2-7 SAFETY (A-C) GROUNDING

WARNING

2-8 For safety it is imperative that the metal chassis be kept at ground potential. If a 3-wire safety a-c input cord and a properly grounded outlet is used, this is taken care of automatically. However, if only a 2-wire a-c input cord or an adaptor for a 3-wire, a-c input cord is used, the pigtail wire of the adaptor or the metal chassis of the power supply must be returned to a good a-c ground via P1—3 or terminal (3) on the PC—2.

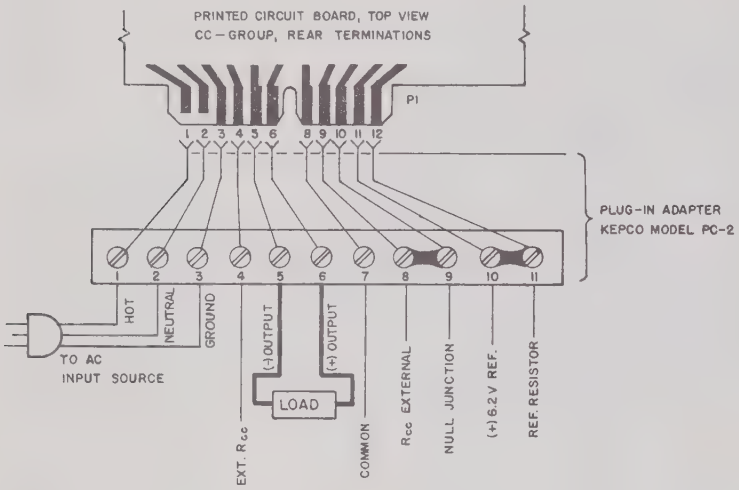


FIG. 2-2 REAR TERMINATIONS.

NOTE: If PC—2, optional plug-in adaptor is not used jumper connections must be provided on the mating jack for P1, the connector on the CC module, between pins (11)—(12) and (9)—(10).

CAUTION

Before a-c turn-on *either* the load must be connected to front or rear output terminals, *or* the shorting link must be in place.

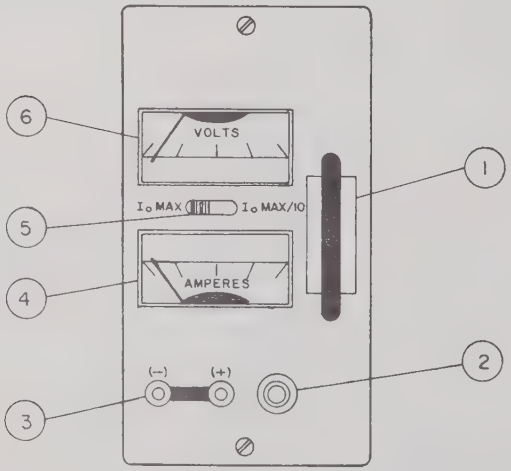


FIG. 2-3 TERMINATIONS AND CONTROLS, FRONT PANEL.

NO.	TERMINATIONS OR CONTROL
1.	A-C POWER SWITCH AND PILOT LIGHT COMBINATION (SDS101).
2.	10-TURN OUTPUT CURRENT CONTROL (R101).
3.	OUTPUT TERMINALS, REMOVE LINK FOR LOAD CONNECTION.
4.	OUTPUT CURRENT METER (M101), Scales: I_o max. and I_o max/10.
5.	OUTPUT CURRENT RANGE SELECTOR: 0 – I_o max, 0 – I_o max/10.
6.	OUTPUT VOLTAGE (COMPLIANCE) METER (M102).

TABLE 2-2 TERMINATIONS AND CONTROLS, FRONT PANEL.

2-9 D-C (SIGNAL) GROUNDING AND ISOLATION

2-10 The d-c output terminals of the CC Current Stabilizer are isolated from the a-c power line and from the chassis. Since no d-c connection to the chassis exists, either side of the supply may be grounded or a maximum of 500V (d-c or a-c peak-to-peak) can be connected between chassis and either output terminal.

2-11 PRELIMINARY CHECK-OUT PROCEDURE

CAUTION

An ***open circuit*** represents a fault condition for a current source (the equivalent of a ***short circuit*** for a voltage source). Current stabilizers in the CC Design Group must therefore be operated with a load across the output at all times. (Fixed voltage limiting at about 150% of the rated compliance is provided, the actual value depending upon the a-c input source.)

2-12 Before final installation a simple functional check may be performed as follows:

a) Refer to rear termination diagram (FIG. 2-2) and par. 2-4 for correct primary a-c connections. Connect supply to power line.

b) With the supplied shorting link across the output terminals, turn A-C POWER switch "on." The a-c indicator light (part of A-C POWER switch) should energize. Turn the CURRENT CONTROL slowly through its range and observe the OUTPUT CURRENT METER. The output current should increase smoothly from zero to the maximum rated output current. The OUTPUT VOLTMETER will remain at zero, since the voltage output (compliance) is zero under short-circuit condition. If voltmeter test is desired, refer to SECTION III for load resistor selection. Shut A-C POWER SWITCH "off." This concludes the preliminary check-out.

2-13 INSTALLATION

2-14 Kepco modular plug-in type power sources offer a wide variety of mounting possibilities (Refer to par. 1-9, ACCESSORIES). Whether single case, multiple housing or rack-installation is planned, installation consists simply in carefully sliding the module into one of the cabinets, making certain the printed circuit board connector of the unit has made positive contact with mating plug in the housing. Once the two holding screws on top and bottom of the front panel have been fastened, the unit is ready for operation.

2-15 COOLING

2-16 Modular units installed in single or multiple housing or in rack cabinets must have sufficient air flow for effective convection cooling. Perforated side covers and tops must be kept clear from obstructions. In rack-installations, care must be taken that the temperature inside the rack does not exceed the specified ambient temperature. Where large amounts of heat are dissipated within the cabinet, power supplies should be "force air cooled."

SECTION III – OPERATION

3-1 OPERATING CONSIDERATIONS FOR CURRENT STABILIZERS

3-2 For users not thoroughly familiar with stabilized current sources, a few general remarks about these devices may be in order. The properties which distinguish a current stabilizer can perhaps best be shown by analogy with an equivalent voltage stabilizer. For any given range of load resistances, the latter keeps its output voltage constant, while its load current tracks the value of the load resistance. A current stabilizer, on the other hand, keeps its output current constant, while its output voltage "complies" with the demands of the load resistance and changes accordingly. (For this reason, the output voltage of a current stabilizer is sometimes termed the "Compliance Voltage.")

3-3 The CC Current Stabilizer has a load range (0 to $R_L$max.), the limit of which ($R_L$max.) is determined by its maximum rated compliance voltage ($E_O$max.) and the specific output current value (I_{OS}), set by the front panel output current control (or by a remote control): $R_L\text{max.} = E_O\text{max.}/I_{OS}$; (Eq. 1)

where "$R_L$max." represents the MAXIMUM load resistance which can be connected across the output of the CC Current Stabilizer for a specific value of the output current (I_{OS}), set by the current control, and $E_O$max. is the maximum rated output (compliance) voltage of the particular CC model.

3-4 By means of the equation above (Eq. 1) one can quickly determine whether a specific CC model is suitable for delivering stabilized output current to a given load when the load requirements are defined. If the load resistance ***exceeds*** the value derived from the equation (Eq. 1), loss of stabilization results, since the CC Current Stabilizer can, under the conditions given by Eq. 1, no longer supply the necessary (higher) compliance voltage. For any load resistance ***lower*** than that derived from Eq. 1, the CC Current Stabilizer will adjust its compliance voltage to the appropriate value, while keeping the output current stabilized. The load range for any given output current (I_{OS}, set by the current control) is, therefore, from zero to $R_L$max., where "$R_L$max." is derived from Eq. 1. An illustration of the above discussion is provided by FIG 3-1, while the output ratings of ***all*** CC models are listed in Table 3-1.

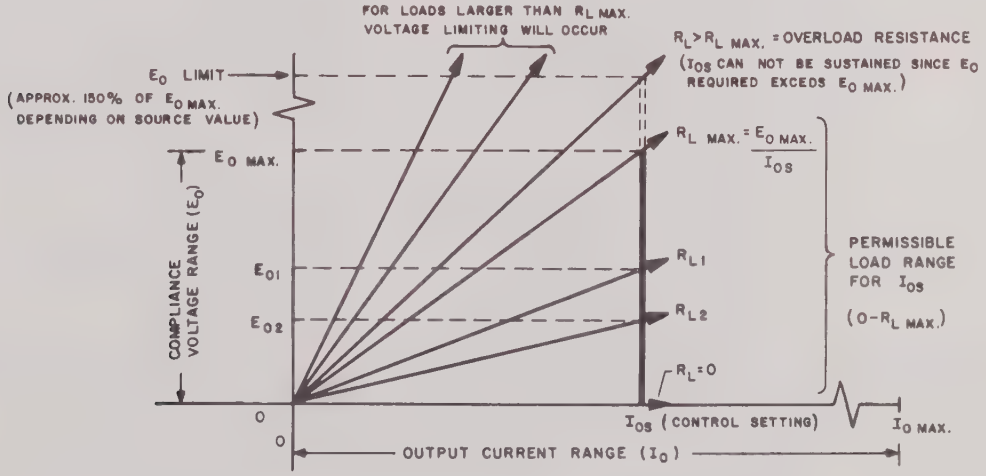

FOR LOADS LARGER THAN R_L MAX. VOLTAGE LIMITING WILL OCCUR
$R_L > R_L$ MAX. = OVERLOAD RESISTANCE (I_{OS} CAN NOT BE SUSTAINED SINCE E_O REQUIRED EXCEEDS E_O MAX.)
E_O LIMIT (APPROX. 150% OF E_O MAX. DEPENDING ON SOURCE VALUE)
E_O MAX.
R_L MAX. = E_O MAX. / I_{OS}
COMPLIANCE VOLTAGE RANGE (E_O)
E_{O1}
E_{O2}
R_{L1}
R_{L2}
R_L=0
PERMISSIBLE LOAD RANGE FOR I_{OS} (0-R_L MAX.)
0
0
I_{OS} (CONTROL SETTING)
I_O MAX.
OUTPUT CURRENT RANGE (I_O)

FIG. 3-1 LOAD RANGE FOR CURRENT STABILIZER

MODEL	LOAD RANGE (AT I_O MAX.)	COMPLIANCE VOLTAGE RANGE (E_O)	OUTPUT CURRENT RANGE (I_O)
CC 7–2	0–3.5 ohms	0–7 volts	0–2 amperes
CC 15–1.5	0–10 ohms	0–15 volts	0–1.5 amperes
CC 21–1	0–21 ohms	0–21 volts	0–1 ampere
CC 40–0.5	0–80 ohms	0–40 volts	0–0.5 ampere
CC 72–0.3	0–240 ohms	0–72 volts	0–0.3 ampere
CC 100–0.2	0–500 ohms	0–100 volts	0–0.2 ampere

TABLE 3-1 LOAD RANGES, CC SERIES.

3-5 STANDARD OPERATION, LOCAL CONTROL

3-6 With the CC rear PCB connector terminated either with a simple mating connector, the PC–2 plug-in adaptor (rack-mounted) or a case adaptor, the unit may be connected to the a-c power source and is ready for operation. The load may be connected to the rear barrier-strip or the front terminals. Standard jumper-link connections are shown in FIG. 3-2 below. Links and load connections must be tight and secure for proper operation. If no external load is connected, the output terminals must be shorted by link or other connection to provide a path for the current.

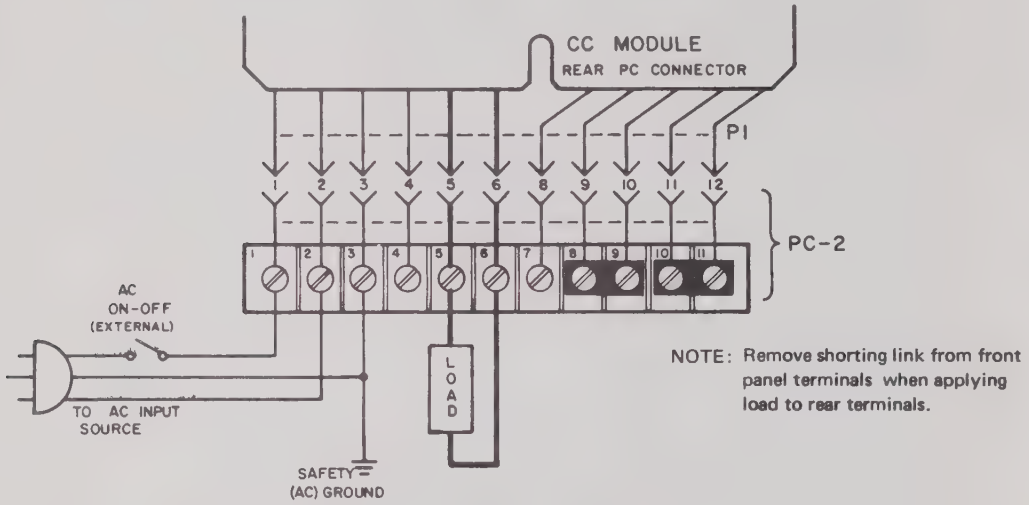


FIG. 3-2 REAR TERMINATIONS FOR STANDARD LOCAL OPERATION.

3-7 The connection diagrams in this section (see FIG. 3-2) show the barrier-strip terminations on the plug-in adaptor (part of any cased unit) and on the equivalent PC–2 adaptor (part of any rack-mounted unit). If the uncased unit is to be terminated by the mating connector for the printed circuit plug (P1) only, the jumper links shown on the barrier-strip adaptor (PC–2) must be duplicated by wire jumpers on the mating jack for the rear PC connector (P1).

NOTE: 1) SINCE THE KEY ON P1 TAKES THE PLACE OF PIN #7, THE BARRIER-STRIP TERMINAL NUMBERS DO NOT CORRESPOND TO THE PIN NUMBERS ON P1.

NOTE: 2) A FOLD-OUT DIAGRAM IS PROVIDED AT THE END OF SECTION III, RELATING THE BARRIER-STRIP CONNECTIONS, SHOWN IN ALL OPERATING DIAGRAMS, TO THE CIRCUITRY OF THE CC MODULE.

NOTE: 3) REFER TO SECTION II (FIG. 2-3) FOR THE LOCATION OF ALL OPERATING CONTROLS.

3-8 The OUTPUT CURRENT RANGE SELECTOR should be placed according to the operating range desired. Two ranges are available:

a) In the "$I_O$max." position, the full output current ($I_O$max.) of the unit is available and the ammeter reads on its upper scale.

b) For applications requiring less than one-tenth ($I_O$max./10) of the rated output current, the OUTPUT CURRENT RANGE SELECTOR should be placed in the "$I_O$max./10" position. In this position, only one-tenth of the output current is available and the ammeter reads on its lower scale.

3-9 The purpose of the OUTPUT CURRENT RANGE SELECTOR is to provide the best current stabilization at low output currents. This range switch is not a meter range switch; i.e., it will not show the same output current on a different meter scale when activated. Although it will operate the ammeter on a lower scale, this function is only incidental to its main purpose, namely to switch output ranges.

CAUTION

EXTREME CARE SHOULD BE EXERCISED WHEN SWITCHING OUTPUT RANGES UNDER LOAD. ALTHOUGH THE FRONT PANEL AMMETER IS PROTECTED, A 10:1 CURRENT INCREASE MAY DAMAGE A SENSITIVE LOAD.

3-10 INTRODUCTION TO THE CONTROL EQUATION

3-11 To familiarize the user with the terminology and the basic equations pertaining to the CC, a simplified analysis of the circuit will be presented and the transfer function derived. The significant electrical components of the current stabilizer circuit can be represented as shown in FIG. 3-3.

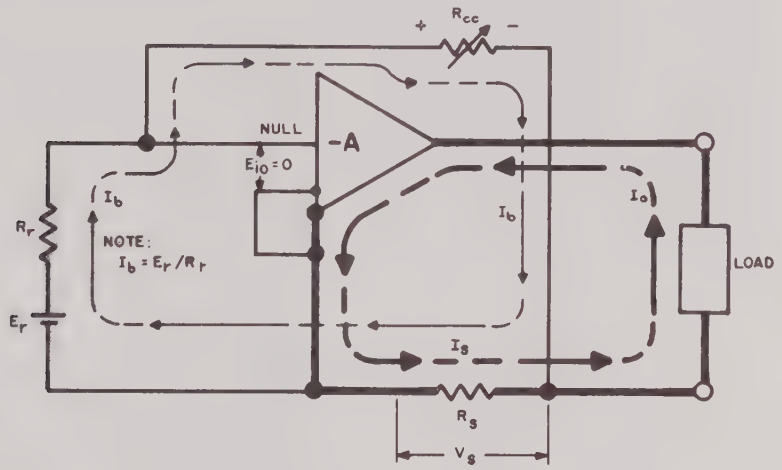


FIG. 3-3 IDEAL CURRENT STABILIZER.

3-12 The Kepco CC Current Stabilizer employs a simple comparison circuit using an integrated operational amplifier with high gain and low bias current to obtain a true null terminal, at which the output current, sampled across R_S, can be compared with a zener stabilized reference (E_r) through a pair of proportioning resistors, R_r and R_{CC}. R_r is made trimmable and is used for calibration; R_{CC} is a variable rheostat, either the front panel current control or an external programming resistance.

The voltage across the amplifier's input terminals, forming the null is E_{io}.

Assuming that E_{io} is 0, the reference E_r establishes a current $I_b = E_r/R_r$ and

$$I_bR_{cc} + (I_b - I_o)R_s = E_{io} = 0.$$

Therefore: $I_bR_{cc} + I_bR_s = I_oR_s$

and $I_o = I_b\left(\frac{R_{cc}}{R_s} + 1\right)$ which limits $I_o = I_b$ as $R_{cc} \rightarrow 0$.

3-13 In the CC models, a special zeroing control is provided to offset E_{io} from zero by an amount equal to I_bR_s.

Thus: $I_bR_{cc} + (I_b - I_o)R_s = I_bR_s$ (not zero).

and: $I_bR_{cc} - I_bR_s + I_bR_s = I_oR_s$

cancelling terms $I_o = \frac{I_bR_{cc}}{R_s}$ a simpler expression in which I_o approaches zero, as $R_{cc} \rightarrow 0$.

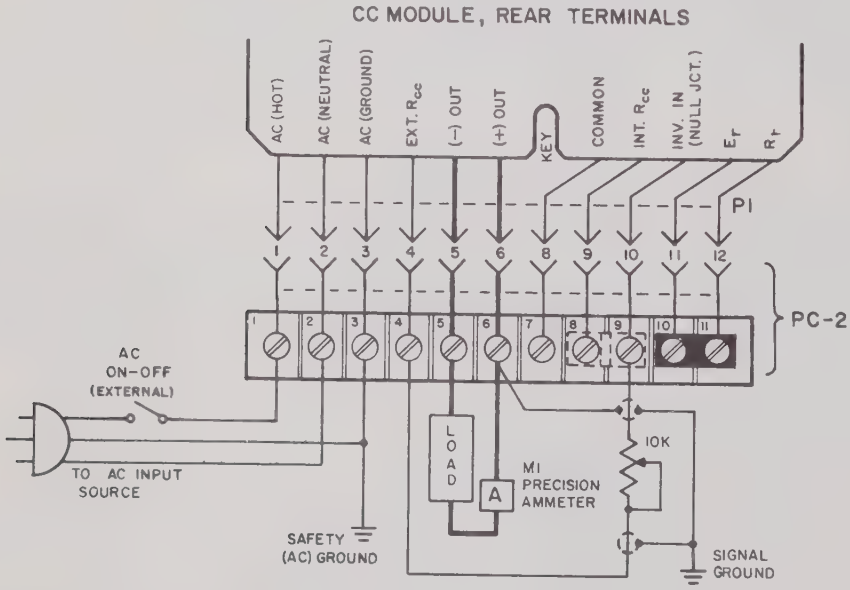
3-14 Other modes of output control include remote voltage programming by retaining a fixed gain factor (R_{cc}/R_s) and replacing the internal (fixed) reference voltage by an external variable control voltage. The output can also be controlled by inverse resistance (conductance) variations making the reference resistor (R_r) adjustable. Some of the many possible programming methods are described and illustrated in the following paragraphs.

3-15 ADJUSTMENTS FOR PRECISION PROGRAMMING RATIO

3-16 All current stabilizers in the CC group are factory-adjusted for an output range from zero to their maximum rated current (on both operating ranges) with the CURRENT CONTROL at its maximum counterclockwise and clockwise position, respectively. Since a "sensing voltage" (V_S) of 1 volt (at maximum output current) is used for both ranges, and the control resistor (R_{CC}) has a value of 10 K ohm, a "programming ratio" of 10,000 ohms per volt of sensing results for the internal control system. This control ratio may be retained when programming externally, or it can be altered, keeping in mind that V_S = 1V at maximum output current. In either case, when using external resistance to control the output, the programming ratio must be readjusted if precise results are expected. Adjustment procedures for the standard as well as for a modified programming ratio are given below.

3-17 PROCEDURE FOR PROGRAMMING RATIO ADJUSTMENT (STANDARD)

a) With the external programming resistor connected as shown (Refer to FIG. 3-4), and a precision ammeter in series with the load (optional, since the panel ammeter may be used if an accuracy of ±3% is sufficient), locate the "I_b adj." and "E_{io} null" controls on the printed circuit board (Refer to FIG. 2-1).



NOTES:
1) Remove links (8)–(9).
2) Alternately, (–) out (5) may be signal grounded.
3) See fold-out diagram at the end of this section.
4) Remove shorting links from front panel terminals.

FIG. 3-4 PROGRAMMING RATIO ADJUSTMENT FOR REMOTE RESISTANCE CONTROL.

b) With the external "Current Control" at zero ohms, adjust "E_{io} null" (R18) until zero output current is read out on the ammeter (M1).

c) With the external "Current Control" at 10 K ohms, adjust "I_b adj." (R23) until maximum output current is read out on the ammeter (M1).

d) Recheck zero (b). This concludes the programming ratio adjustment.

3-18 REMOTE RESISTANCE PROGRAMMING

3-19 The output current of the CC Current Stabilizer may be varied by means of an external current control resistance connected between rear terminals (4) and (9). If the standard control ratio is retained (see par. 3-17 for precision adjustment), a total resistance of 10 K ohms will control the output from zero to the maximum rated output current in either range. The control resistance may be fixed, continously adjustable, or step-controlled or it may be a combination of these.

3-20 CAUTION. When fixed resistors are switched or step-controlled, the switching device must have " make before break" contacts, so that the control circuit does not open during transfer. Programming resistors should be high quality units, with low temperature coefficients (20 ppm or better).

3-21 CC Current Sources may be remote controlled by other than the standard programming ratios. If for example a precision rheostat of 3000 ohms is available, a simple adjustment will allow the user to control the output over both ranges.

3-22 PROCEDURE FOR PROGRAMMING RATIO ADJUSTMENT (NONSTANDARD).

a) Proceed exactly as described in par. 3-17a. In addition, connect a 40 K trim-rheostat between rear terminals (9) and (10). (Refer to FIG. 3-5.)

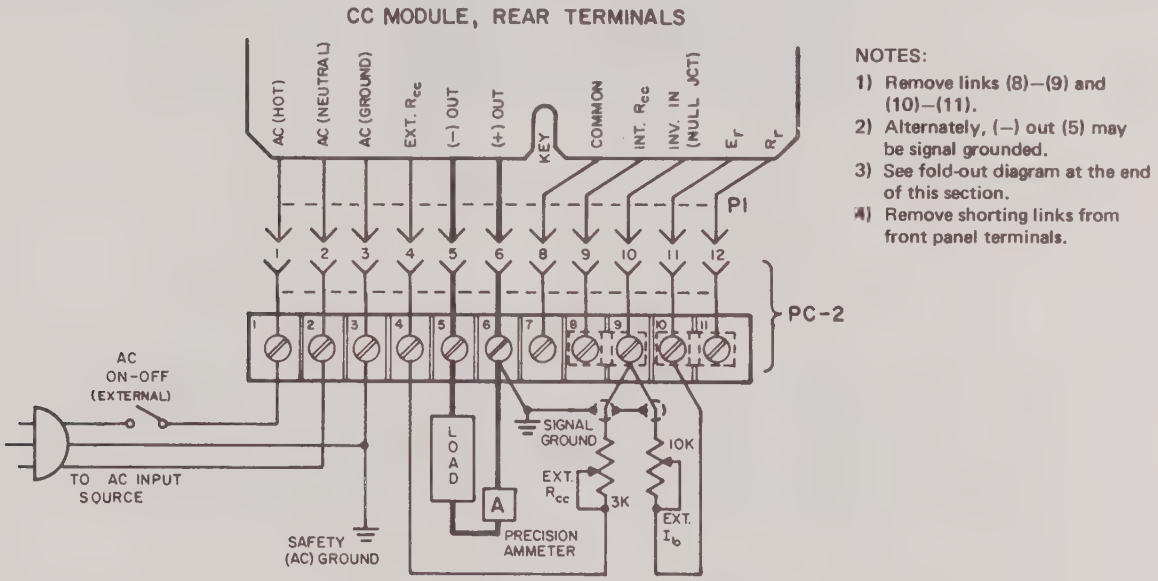


FIG. 3-5 RESISTANCE PROGRAMMING AND ADJUSTMENT FOR NONSTANDARD PROGRAMMING RATIO.

b) With the external "Current Control" at zero ohms, adjust "E_{io} null" (R18) until zero current is read-out on the ammeter (M1).

c) With the external "Current Control" at 3000 ohms, adjust the external "I_b adjust" until maximum rated current is read-out on the ammeter.

d) Recheck zero. This concludes the programming ratio adjustment. The output current can now be adjusted from zero to its maximum value on either range.

3-23 REMOTE PROGRAMMING BY A CONTROL VOLTAGE SOURCE

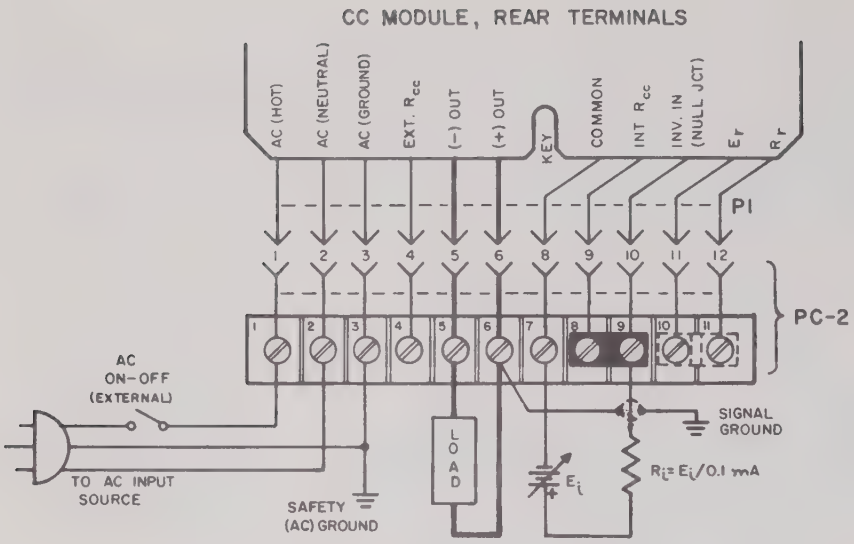
3-24 The output current of the CC Current Stabilizer can be controlled by means of an external signal voltage. This external signal voltage (E_i) now provides the necessary control current (I_b) formerly delivered by the (fixed) internal reference source (E_r). Using the previously derived simplified transfer function, we can write:

$$I_o = E_i/R_i(R_{cc}/R_s) \text{ and: } E_i/R_i = I_b$$

where the new terms are the external signal source (E_i) and the input resistor (R_i), which should always be selected such that $E_i max./R_i = 0.1$ mA $= I_b$ if the internal front panel current control resistor (R_{cc}) is used with the internal sensing resistor (R_s). Other values of programming current (I_b) may be chosen if the internal current control (R_{cc}) is replaced with an external component. (See par. 3-21, 3-22 for programming with nonstandard programming ratio.)

3-25 Voltage programming with the CC may be performed simply by disconnecting the internal reference source (E_r) (opening terminals [10]—[11] on the rear barrier-strip) and replacing it with the external control voltage (E_i) and the proper coupling resistor (R_i). Varying E_i will now change the output current proportionally. (Refer to FIG. 3-6.) R_i is selected such that $E_i max./0.1$ mA $= R_i$.

3-26 Due to its considerable bandwidth and slewing speed, the CC Current Stabilizer can be effectively used as a unipolar amplifier with potentially high power gain. It must be remembered, however, that the CC is a unipolar device. Since its output can only vary in one direction, the input source must also be unipolar (positive-going with respect to the "Common" terminal) or, the d-c output level must first be set (by d-c biasing, using the internal reference source) in such a way that it can accommodate the amplified signal if the input is bipolar. An example of programming with a bipolar input source is given below.



NOTES:
1) Remove links (9)—(10).
2) Either (+) output, as shown, or (-) output may be signal grounded.
3) See fold-out diagram at the end of this section.

FIG. 3-6 REMOTE OUTPUT CURRENT CONTROL BY VOLTAGE.

3-27 Example: A Model CC 100—0.2M is to be sine-wave programmed over its full output current range from a generator having a bipolar output of 2V peak-to-peak and an output impedance of 600 ohms. Since the external programming signal is ***BIPOLAR*** and the CC Current Stabilizer can only respond in ***one*** direction (positive with respect to the common [+] output terminal). The output of the CC Current Stabilizer must first be set to a d-c output level which can accommodate the output signal swing. Since the maximum output current off this particular model is 0.2A, assume the d-c output will be set to 0.1A, so that the amplified sine wave signal can swing equally "around" the d-c bias level of 0.1A. (See FIG. 3-7.)

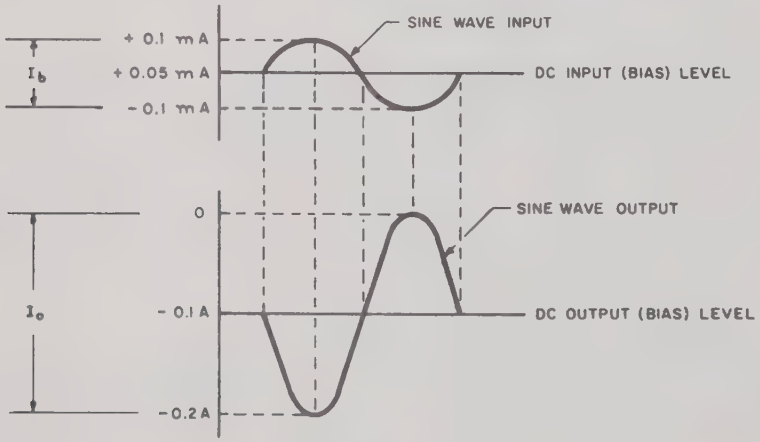


FIG. 3-7 SINE WAVE PROGRAMMING.

3-28 With the front panel current control in the maximum ***clockwise*** position, the CC Current Stabilizer yields maximum rated output for a fixed control current (I_b) of 0.1 mA. If we supply ***one half*** of I_b (0.05 mA) from the fixed reference source and the ***other half*** (±0.05 mA) of I_b from the external programming source, the following expression can be written:

$$I_o = (I_{b1} \pm I_{b2})(R_{cc}/R_s),$$

where I_{b1} is the fixed reference current which produces the d-c output bias (0.1A d-c) and I_{b2} is the programming signal which is constantly changing in polarity and therefore produces the sine wave output around the d-c bias level. (See FIG. 3-7.) It remains to determine the component values necessary to complete the programming circuit:

a) The standard control current (I_b) must be reduced to one-half its former value (I_{b1} = 0.05 mA). This is accomplished by introducing an additional series resistance into the d-c reference voltage circuit. Remove rear link (10)—(11) and connect a 100 K rheostat in place of the link. The rheostat is adjusted later to the exact output level of 0.1A d-c.

b) To produce ±0.05 mA control current (I_{b2}) from the 2V signal source (E_i), the series resistor (R_i) must be: 2V/0.05 mA = 40 K ohms.

c) Connect the external programming source, the load, and the calculated resistors to the CC barrier-strip as shown in FIG. 3-8. Turn the CC Current Stabilizer "on." With a momentary short circuit between rear terminals (4) and (8), adjust ZERO CURRENT CONTROL ("E_{io} Null" = ZERO CURRENT CONTROL, R18) to zero output current. Remove short and adjust external 100 K rheostat for 0.1A output. Turn on signal generator and adjust amplitude for maximum sine wave output without distortion, as observed on an oscilloscope across the output terminals (5)—(6).

d) After the programming set-up has been connected as shown in FIG. 3-8, operation can commence. The sine wave frequency response of the CC under the operating conditions described will be approximately 1.6 kHz, calculated by the relation:

$$f_{max.} = \frac{\text{SLEWING RATE}}{2\pi E_p}$$ where $f_{max.}$ equals the maximum (undistorted) sine wave frequency,

and E_p the peak excursion (1/2 p-p) of the compliance voltage. The "Slewing Rate" of the compliance voltage is equivalent to the specified "Current Recovery," 2 μsec. per volt or 5×10^5 V/sec. Inserting the known values into the equation shown, the result is:

$$f_{max} = \frac{5 \times 10^5 \text{V/sec.}}{6.28 \times .5 \times 10^2 \text{V}} \approx 1.6 \times 10^3 \text{ Hz, or 1.6 kHz.}$$

If the input signal frequency is raised beyond the calculated figure, slope distortion will set in.

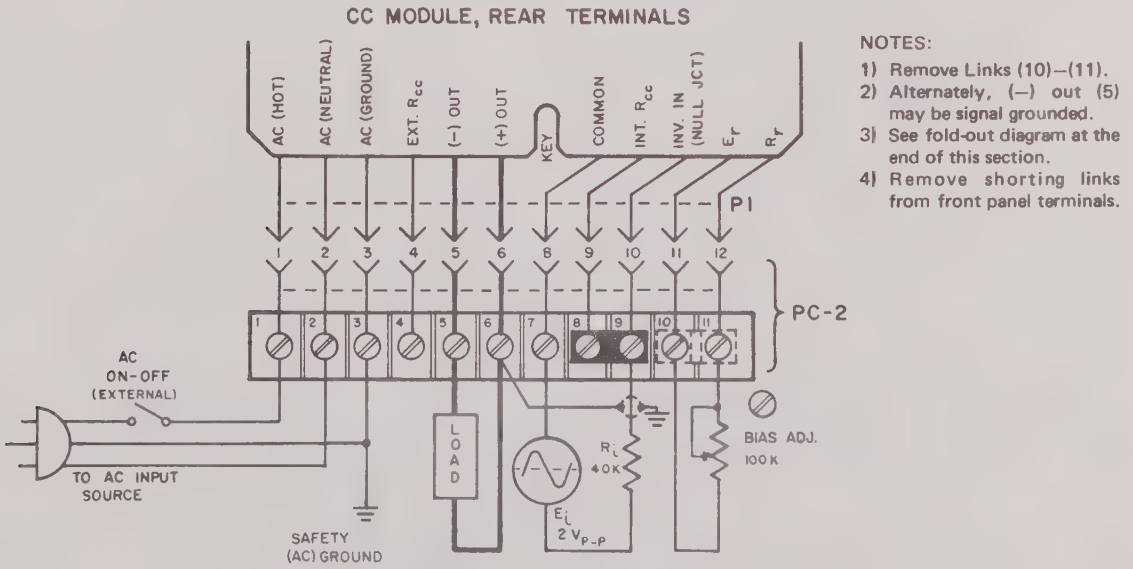


FIG. 3-8 CONNECTIONS FOR SINE WAVE PROGRAMMING.

3-29 Another interesting way of controlling the output current by an external voltage is to connect the programming source directly into the feedback terminals of the current stabilizer. Since the built-in sensing resistors are designed to drop 1 volt at full output current, a 1 volt source connected as shown in FIG. 3-9 will program the CC from 0 to I_o max., as the programming source is varied from 0 to 1 volt.

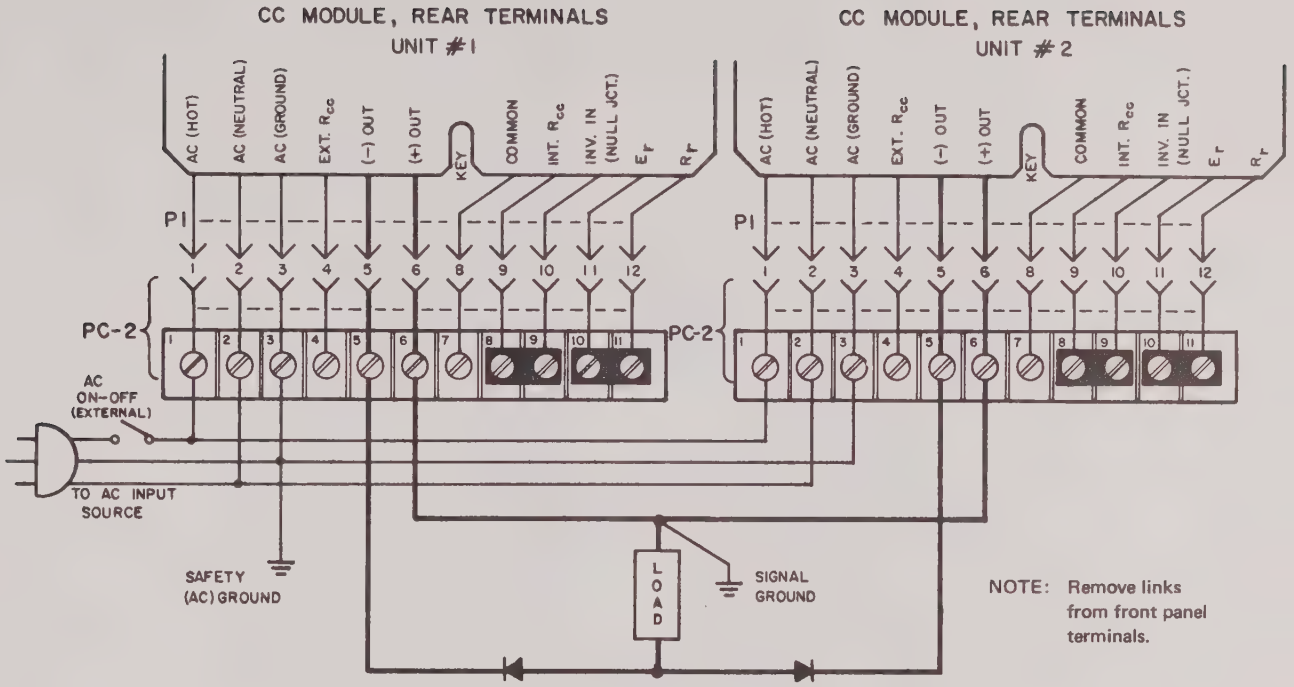


FIG. 3-10 "AUTOMATIC" PARALLEL CONNECTION.

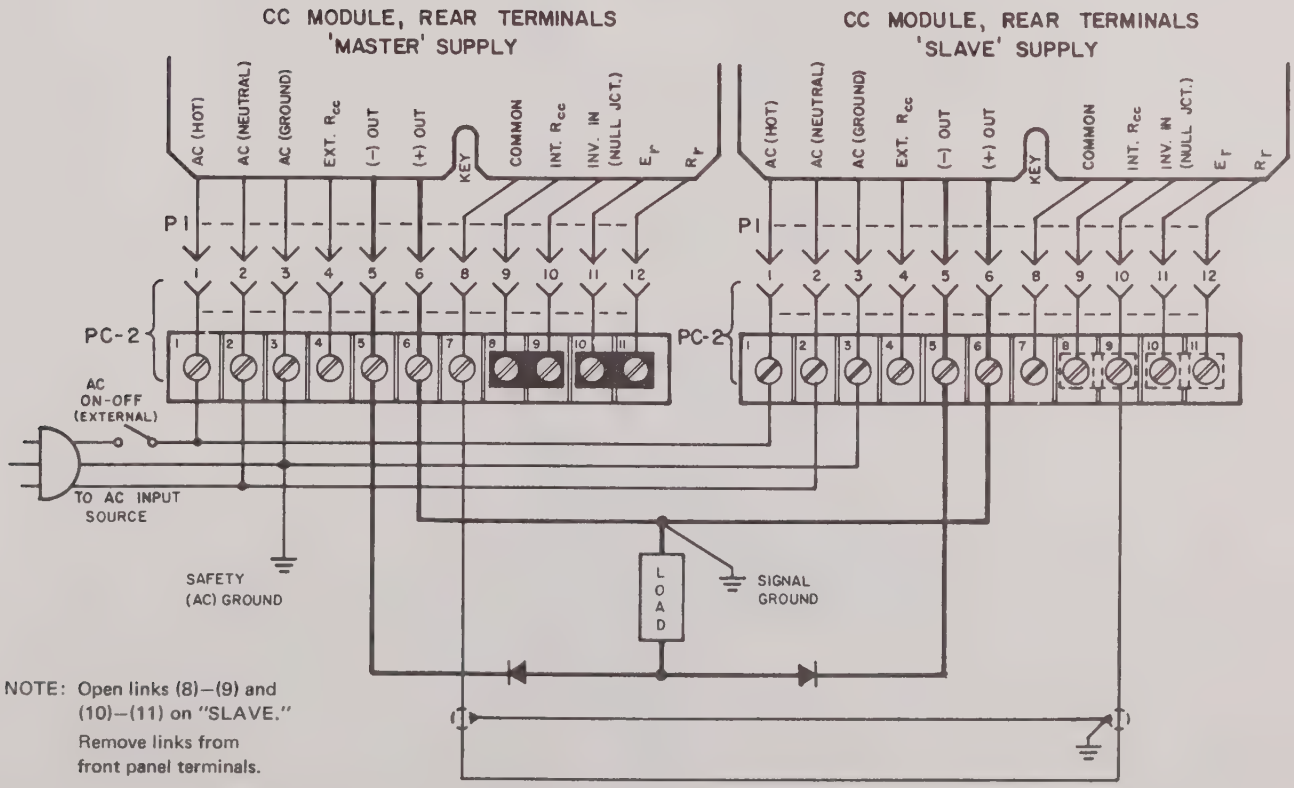


FIG. 3-11 "MASTER/SLAVE" PARALLEL CONNECTION.

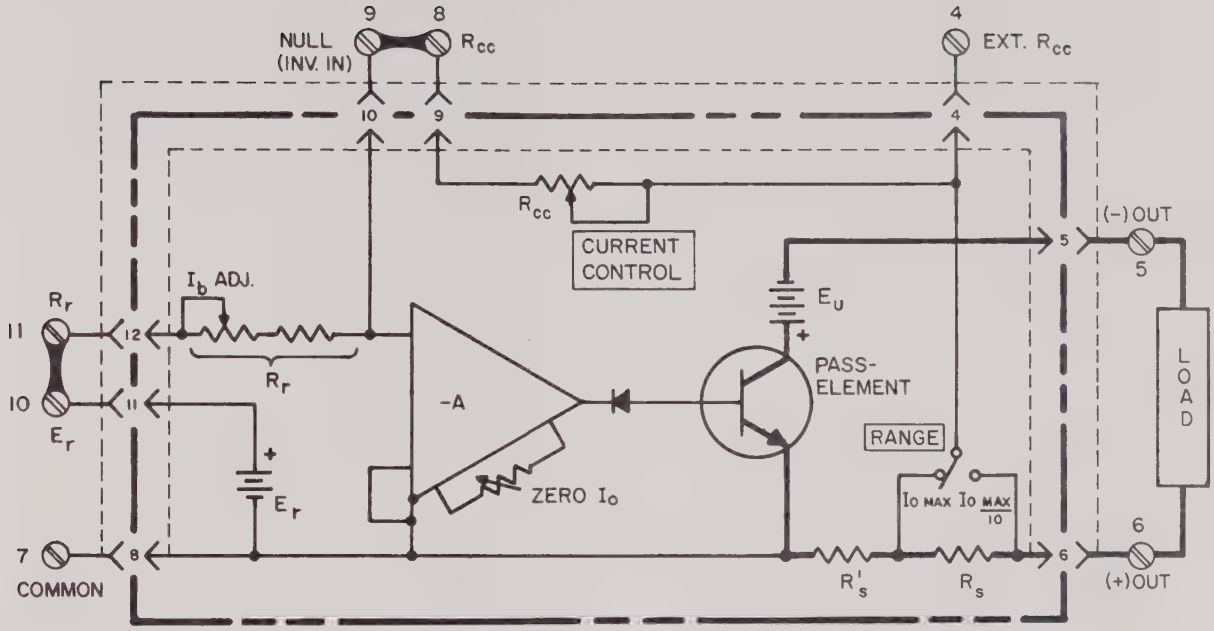
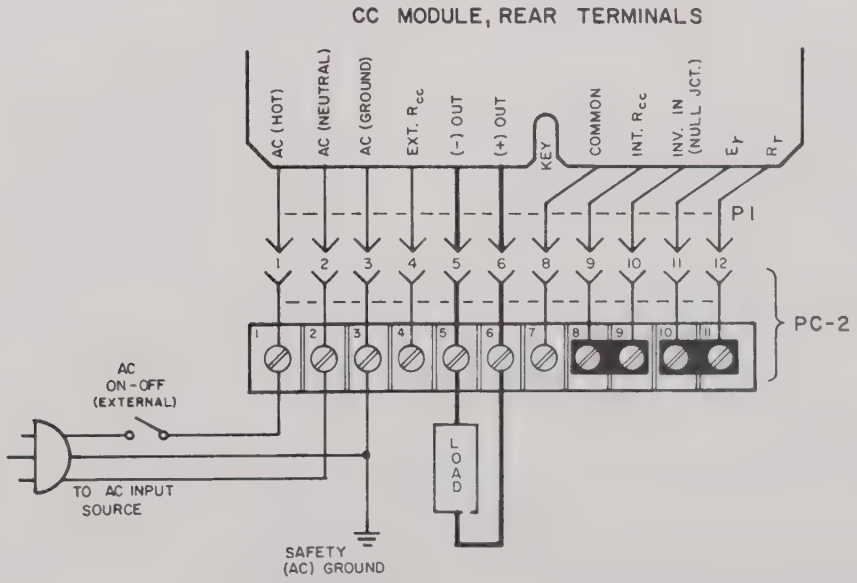


FIG. 3-12 SIMPLIFIED CONNECTION DIAGRAM, CC MODULE.
(SHOWN WITH MODEL PC–2 PLUG-IN ADAPTOR)

NOTES: 1) THIS DIAGRAM MAY BE USED TO ANALYZE PROGRAMMING CIRCUITS. USE IN CONJUNCTION WITH BARRIER-STRIP DIAGRAMS IN SECTION III.

2) A-C INPUT TERMINALS *NOT* SHOWN, SEE BARRIER-STRIP DIAGRAM FOR COMPARISON.



SECTION IV – THEORY OF OPERATION

4-1 GENERAL

4-2 This section contains a discussion of the simplified diagram and a sectional circuit description. The operational Analysis of the current stabilizer and the derivation of the transfer function were treated in par. 3-10 (Introduction to the Control Equation). In the following paragraphs, references given in CAPITAL LETTERS refer to the nomenclature used in FIG. 4-1.

4-3 SIMPLIFIED DIAGRAM DISCUSSION

4-4 The POWER TRANSFORMER converts the source voltage to the required levels to produce, in combination with the appropriate rectifier and filter components, the required d-c operating voltages for the MAIN and AUXILARY POWER SUPPLIES. The MAIN POWER SUPPLY is "in series" with the PASS TRANSISTOR, the CURRENT SENSING RESISTORS and the LOAD, producing the rated output current. The PASS TRANSISTOR changes its series resistance in such a way as to keep the voltage across the CURRENT SENSING RESISTORS constant, thus providing constant output current despite changes in the a-c source voltage or variations in load resistance. The necessary drive for the effective resistance change in the PASS TRANSISTOR is produced by the DRIVER CIRCUIT, which in turn is controlled by the ERROR SIGNAL AMPLIFIER.

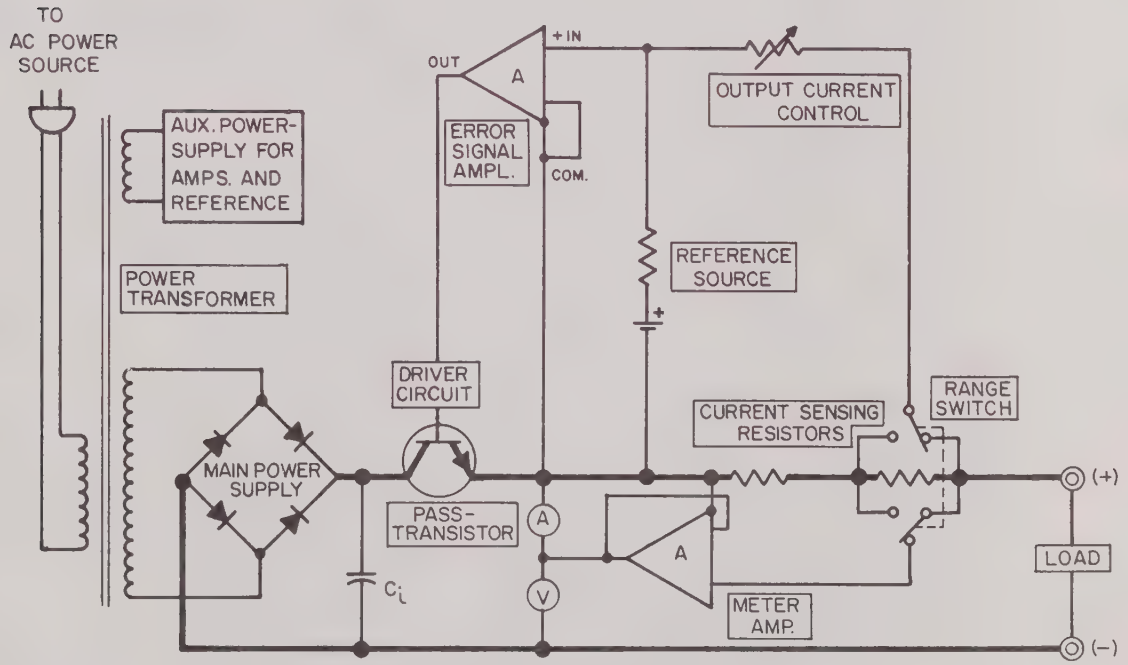


FIG. 4-1 CC SIMPLIFIED DIAGRAM.

4-5 The voltage drop (due to output current flow) across the CURRENT SENSING RESISTORS is continously compared to the REFERENCE SOURCE. As long as an equilibrium exists between these two voltages, the input to the ERROR SIGNAL AMPLIFIER is zero and the output current remains unchanged. A-C input source variations or load changes tend to produce a change in voltage across the CURRENT SENSING RESISTORS, resulting in a difference voltage or error signal at the amplifier input. The ERROR SIGNAL AMPLIFIER, an operational feedback amplifier in the noninverting configuration, feeds directly into the DRIVER CIRCUIT which produces the drive signal for the PASS TRANSISTOR. The PASS TRANSISTOR will change its effective series resistance such as to keep the output constant once more.

4-6 DETAILED CIRCUIT DESCRIPTION. (Refer to Main Schematic, FIG. 6-3.)

4-7 For the purpose of convenient analysis, the circuitry of the CC Series of Current Stabilizers may be divided into several sections, which are subsequently described below:

a) A-C INPUT CIRCUIT. A-C source power is introduced through the rear printed circuit board (PCB), connector (P1), terminals (1) and (2). Terminal (3) is connected to the chassis and should always be returned a-c ground. Once the front panel slide switch/indicator is closed, primary power is applied to the main transformer (T201) and the indicator lamp. T201 has two primary windings which are either connected in parallel (for 115V a-c service) or in series (for 230V a-c service). The fuse (F1) protects the primary winding of T201 from excessive current.

b) MAIN D-C POWER SUPPLY. The main d-c power is derived from a secondary winding on the main transformer (T201). Rectification and filtering is performed by a conventional bridge rectifier circuit (CR5,6,7,8) and an electrolytic capacitor (C3). The main d-c power supply delivers the rated output current and the operating voltage for the pass transistor(s).

c) PASS TRANSISTOR CIRCUITRY. The pass transistor (Q201) is connected in series with the plus (+) output terminal, the current sensing resistors (R16,26,27), the external load and the (unregulated) main d-c supply. The output current flowing in the loop is kept constant, regardless of external changes in load resistance or a-c input voltage, since the effective series resistance of the pass transistor is altered in response to these changes. The base drive needed to produce this corrective action by the pass transistors is supplied by the driver stage (Q2) which in turn is driven by either the error signal amplifier (A_V), or the current limit amplifier (Q3,4). Some CC Current Sources (see Main Schematic, FIG. 6-3) have two pass transistors in a parallel connection (Q201 and Q202.

d) ERROR SIGNAL AMPLIFIER (A_V). This device is a d-c coupled, high-gain operational feedback amplifier, used in the noninverting configuration. Its main function is to amplifiy the difference voltage (error-signal) existing between its null junction (input) and common when an imbalance exists. The input of the amplifier is made available externally (via P1-10) for applying input signals (with respect to "common", P1-8) in remote programming applications. Error, as well as input signals are amplified by A_V to a level suitable to pass the gate circuit and drive Q2.

e) CURRENT LIMIT CIRCUITRY. The current limiting circuitry has the function to prevent output current flow beyond the maximum rated value. It performs this function by taking control of the pass transistor as soon as this value is reached. The differential inputs of the current limit amplifier (Q3,4) are connected to a current sensing resistor R_S (R16) and to reference voltage. The voltage drop across R_S (due to load current flow) is continuously compared to the preset voltage at the "Maximum Output Current" control (R15). As long as the voltage developed across R_S is less than the preset voltage level at R15, the current amplifier will be biased to its inactive state and will have no effect on the output. Both the current limit amplifier and error signal amplifier (A_V) are coupled through their respective gate diodes (CR16,17) to the driver transistor (Q2). The amplifier with the larger (negative) output will control the pass elements while the other amplifier is decoupled. Since the voltage drop across the sensing resistor (R16) is proportional to the output current, and the "I_O max." control may be set to a voltage proportional to the desired output current, the current amplifier is inactive as long as the output current does not exceed the preset level. If the output current does increase, however, the current amplifier will produce an output signal more negative than A_V, thereby taking control away from the voltage amplifier A_V and limiting the output current sharply in the process.

f) AUXILIARY SUPPLIES

1) AMPLIFIER POWER SUPPLY. This full-wave, capacitor-filtered source consists of a center tapped winding on T201, silicon rectifiers CR1, CR2 and the filter-capacitor, C1. A constant current stage (Q1) followed by a string of zener diodes (CR11, CR12, CR13, CR14) provides the operating voltages for the amplifiers and is the source of the temperature-compensated reference voltage (CR21). The positive reference voltage serves as the comparison source for the error-signal amplifier (A_V) and produces the control current.

2) DRIVER COLLECTOR SUPPLY. A half-wave, capacitor-filtered supply is derived from a winding on T201, rectified by silicon diode CR4 and filtered by C2. It delivers collector voltage to the driver transistor (Q2). R5 is a bleeder and CR15 is a coupling diode to the diode gate.

3) I_{cbo} SUPPLY. The operating voltages for the I_{cbo} circuitry are derived from the main power supply. Q5 is biased by the voltage drop across the series diodes (CR9,10) in such a way as to draw a relatively constant current, thus providing a current sink for the I_{cbo} of the pass elements. This ensures positive cutoff, especially at high operating temperatures.

SECTION V – MAINTENANCE

5-1 GENERAL

5-2 This section contains instructions for the maintenance, internal adjustments (as far as not covered in previous sections) and the performance of test measurements on the CC Current Stabilizers. Conservative rating of all components and noncongested layout should keep maintenance problems to a minimum. If trouble does develop, however, the easily removable plug-in board feature of the main component board provides exceptional accessibility to all components of the instrument.

5-3 DISASSEMBLY. (Refer to FIG. 5-1)

5-4 The main component board (PCB 1 – A1) may be disassembled for servicing by loosening and removing its (4) mounting screws and disconnecting the (3) mating plugs. ATTENTION: When reassembling the printed circuit board to the main chassis, the distance from the rear of the front panel to the extreme outer edge of the main component board must be 15 inches ±1/32, to insure proper fit into the case of rack adaptor.

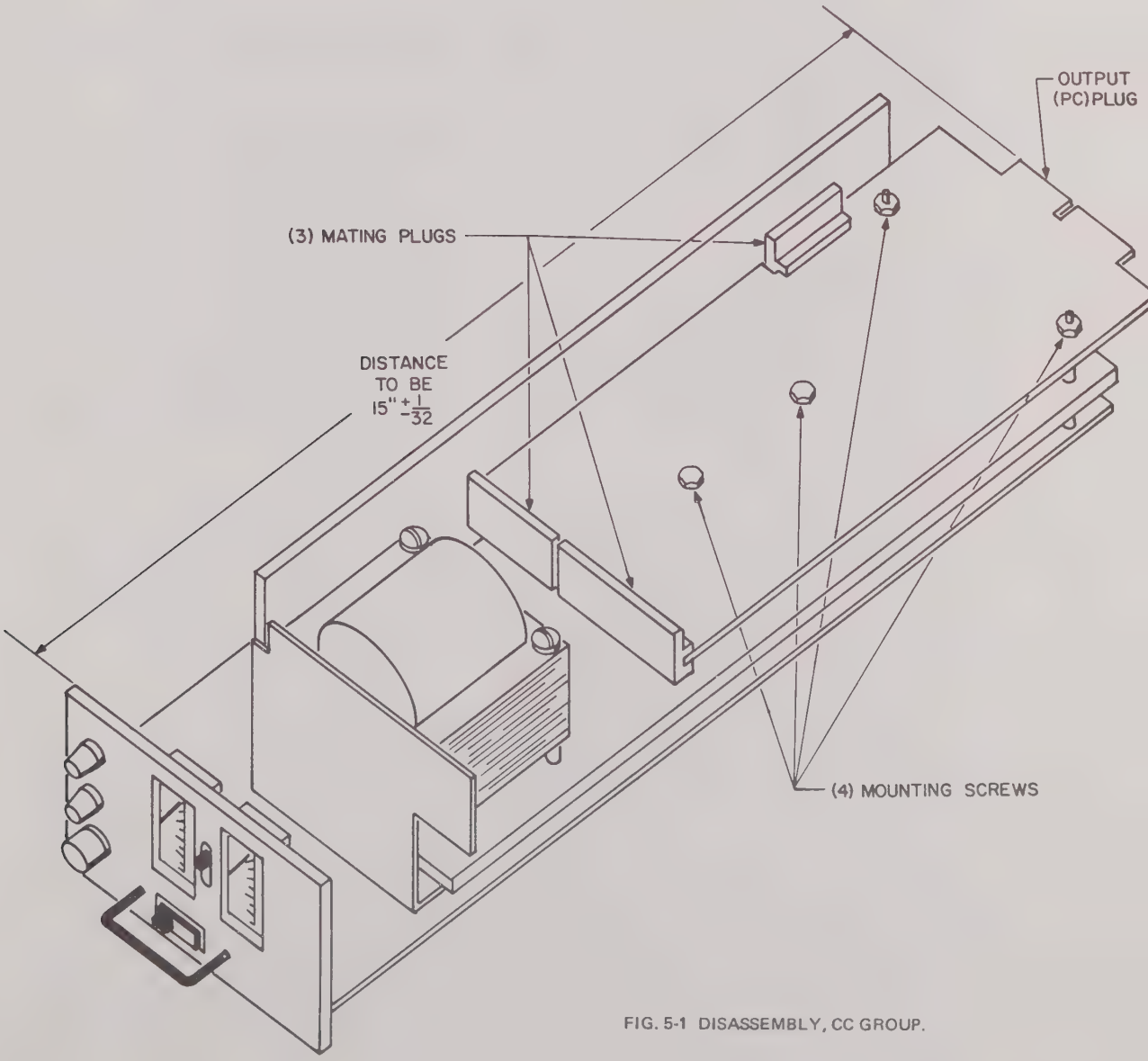


FIG. 5-1 DISASSEMBLY, CC GROUP.

5-5 INTERNAL ADJUSTMENTS

5-6 A listing of all internal controls and their adjustment procedures is presented in Section II of this manual (refer to par. 2-3, "Terminations"). The "zero" and "maximum" output current calibration procedure has been described in Section III (refer to par. 3-15, "Adjustments for Precision Programming Ratio"). Lag network adjustment and overcurrent calibration is described below:

5-7 A-C STABILITY ADJUSTMENT

5-8 The wide-band characteristics of a high-speed current stabilizer may give rise to "ringing," "overshoot," or oscillation at the output, especially when operating into loads which are not purely resistive. In addition to the fixed, internal stabilization networks in the operational amplifier of the CC, an ***adjustable*** lag network has been provided to facilitate operation under varying load conditions. The lag control is accessible from the rear and should be adjusted without removing the instrument from the case or rack cabinet (R19, refer to FIG. 2-1).

5-9 This network has been factory-adjusted for amplifier stability when operating into a resistive load. Readjustment is indicated if components affecting the dynamic characteristics of the amplifier must be replaced, or if the load connected to the power supply contains excessive capacitance or inductance causing instability.

5-10 Dynamic instability is usually indicated by high frequency oscillation as observed with an oscilliscope across the power supply load. In such cases, the lag network should be adjusted so that stable operation is resumed.

5-11 OVERCURRENT ADJUSTMENT

5-12 The "I_O max." adjustment is factory set to limit the output current at approximately 105% of the maximum rated value. Readjustment of this control is necessary only after component replacement in the current limit circuit.

5-13 The readjustment may be made conveniently by using the standard test setup as shown in FIG. 5-2. The unit under test is fully loaded (current control full clockwise) and the output monitored (across R_m) by an oscilloscope (vertical sensitivity 0.1 mV or better). Turning the control (R15) counterclockwise should produce a sharp increase in output ripple, indicating the operation of the unit in the current limit region. The control (R15) should now be set clockwise such that the output ripple appears just normal again. The short circuit current may be measured by shorting the load resistor with an ammeter. The overcurrent may be set to LOWER than the given value—the range of the control is approximately from 10 to 120% of I_O max). UNDER NO CIRCUMSTANCES should the adjustment be higher than 105%, since excessive dissipation may destroy the series regulator transistors.

5-14 TROUBLE SHOOTING

5-15 The repair of modern, electrically complex high-speed voltage/current sources or operational devices, requires a thorough understanding of closed-loop feedback systems and experience with solid state circuitry. The nature of a feedback system renders the so-called "Trouble Shooting Charts," containing resistance, voltage/current readings and/or various fault conditions almost useless. A more sophisticated approach is essential, to assist the user in such an approach when a malfunction occurs, this manual contains:

a) An extensive operational theory (Section IV).

b) A circuit description with simplified diagram (Section IV)

c) Detailed diagrams showing internal parts location (Section VI).

d) The main schematic, containing the complete circuitry, all plug-in inter-connections and all significant voltage readings under specified conditions.

5-16 It has been found in our experience, that in many cases of malfunction, the trouble can be traced to external causes. It is suggested, therefore, if suspicion of power source failure is encounted, to disconnect all external programming or input sources and operate the instrument locally, as directed in Section III. If the power supply does not perform in the standard operating mode, the following basic steps may be found useful:

a) NO OUTPUT. Check a-c input source for correct line voltage. Refer to Section II of this manual if the transformer connections are correct for the prevailing a-c input voltage. (Instrument is normally delivered for 115V a-c operation). Check fuse and replace if it is open. For case or rack mounted units: check proper alignment of the printed circuit board connector with its mating plug and realign, if necessary (distance from behind panel to end of PCB plug = 15 inch ± 1/32).

b) HIGH OUTPUT. Unstabilized output is accompanied by excessive a-c ripple, and the output voltage or current cannot be controlled by the standard panel controls. Check rear terminal connections. Secure all jumper links as well as load leads connected to the supply. (Current stabilizers require a load at all times, refer to Section III, par. 3-6.) Proceed to circuit analysis. Unstabilized output indicated as open feedback loop. Check reference voltage, current control resistor, transistors and amplifier. Inspect printed circuit board for visual damage of components.

c) POOR PERFORMANCE. If the instrument is basically functioning but poor performance is evident, inspect the test set up and follow the check-out procedures presented (refer to par. 5-14 as well as FIG. 5-2). Poor d-c performance is usually due to incorrectly connected instrumentation or other faulty measurement techniques. Follow the recommended procedures and refer to the applicable diagrams. High-frequency oscillation as observed at the output or across the load is often due to loads with an excessive reactive component. Inductive loading on this instrument will cause dynamic instability. If the oscillation cannot be damped-out by a readjustment of the "Lag Adj." control as described previously (refer to par. 5-7) a feedback capacitor (trimmer) in the range of 100–2000 pF, connected across rear terminals (4)–(9) will often stabilize the instrument. Although the response of the device will be affected, this compromise is needed in cases where appreciable inductive loading is present.

5-17 PERFORMANCE MEASUREMENTS

5-18 GENERAL. Valid evaluation of the specified power supply parameters requires a controlled enviroment and specialized test equipment. Since, however, acceptance testing or performance checks are a frequent requirement for incomming inspection, periodic maintenance or after component replacement, suggestions for the performance of some significant performance tests are given in the following paragraphs. It must be emphasized that the given procedures must be followed closely if valid results are expected.

5-19 D-C OUTPUT EFFECT MEASUREMENTS

a) REQUIRED INSTRUMENTATION:

1) A-C INPUT SOURCE REGULATOR with provisions for "steeping" the voltage over the specified region (105–115V a-c or 210–250V a-c); a variable autotransformer is adequate, if it is rated to deliver the required a-c input current of the unit under test.

2) RESISTOR LOAD, variable with shorting switch and rated to dissipate the full output power of the unit under test.

3) D-C PRECISION VOLTMETER, differential type, with a resolution of 1 mV or better, for line/load effect measurements.

4) A-C VOLTMETER, "true rms" reading type, with a sensitivity of at least 1 mV full scale.

5) OSCILLOSCOPE, vertical sensitivity of at least 0.1 mV/cm.

6) CURRENT MEASURING RESISTORS, 4-terminal type, one piece rated to drop 1 volt at the maximum output current and one piece rated to drop 1 volt at 10% of the rated maximum output current.

b) The proper application of the 4-terminal network technique in measuring output effects and a-c ripple is of the utmost importance. The principle governing this method of measurement is simply, not to measure any voltage drops due to load current flow, since these drops would be included in the actual parameters which we are trying to determine and would thus falsify the results.

c) Output effects due to source or load variations in the voltage mode of operation are defined as the amount of output voltage change resulting from a specified change in a-c input source voltage or from a change in load resistance. These output effects can be expressed as an absolute change (ΔE_O) or as a percentage in reference to the total output voltage E_O:

$$\% \text{ Output Effect} = \frac{\Delta E_O}{E_O}(100\%)$$

d) Output effects due to source or load variations in the current mode of operation are defined as the amount of output current change resulting from a specified change in a-c input source voltage or from a change in load resistance. The output effects can be expressed as an absolute change (ΔI_O) or as a percentage in reference to the total output current I_O:

$$\% \text{ Output Effect} = \frac{\Delta I_O}{I_O}(100\%)$$

e) RIPPLE MEASUREMENT. Ripple is specified in percentage of the maximum rated output current. To convert the (mV) reading across the measuring resistor to the proper units (mA), the reading must be divided by the value of the measuring resistor:

$$\% \text{ Ripple} = \frac{V_S/R_m}{I_O}(100\%)$$

Careful wire-dressing and shielding, as well as good a-c grounding are of the utmost importance to get valid results (use single ground point as shown in FIG. 5-2).

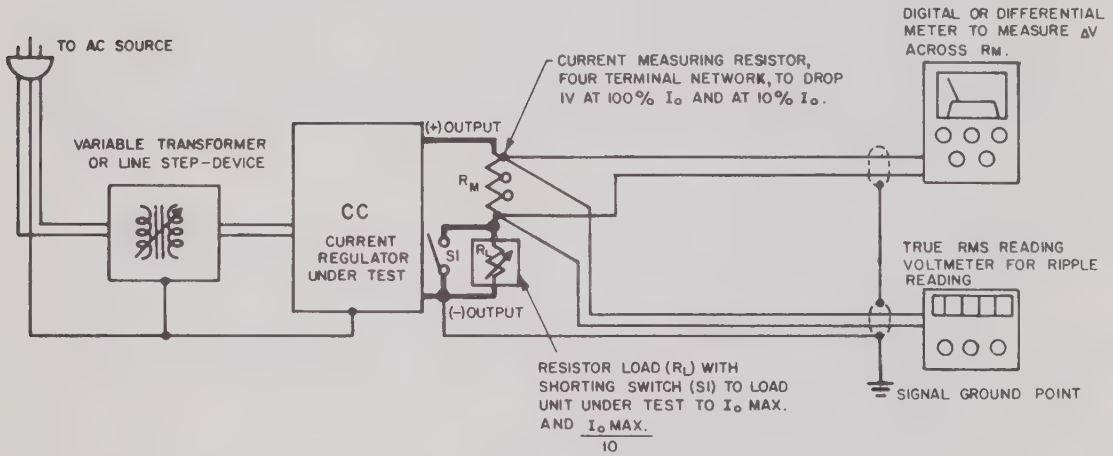

TO AC SOURCE
VARIABLE TRANSFORMER OR LINE STEP-DEVICE
CC
CURRENT REGULATOR UNDER TEST
(+)OUTPUT
(-)OUTPUT
CURRENT MEASURING RESISTOR, FOUR TERMINAL NETWORK, TO DROP 1V AT 100% Io AND AT 10% Io.
RM
SI
RL
DIGITAL OR DIFFERENTIAL METER TO MEASURE ΔV ACROSS RM.
TRUE RMS READING VOLTMETER FOR RIPPLE READING
SIGNAL GROUND POINT
RESISTOR LOAD (RL) WITH SHORTING SWITCH (SI) TO LOAD UNIT UNDER TEST TO Io MAX. AND Io MAX. / 10

FIG. 5-2 TEST SET-UP FOR OUTPUT EFFECTS MEASUREMENTS.

SECTION VI – ELECTRICAL PARTS LIST AND DIAGRAMS

6-1 GENERAL

6-2 This section contains the main schematic, the parts location diagrams, and a list of all replaceable electrical parts. All components are listed in alpha-numerical order of their reference designations. Consult your Kepco Representative for replacement of parts not listed here.

6-3 ORDERING INFORMATION

6-4 To order a replacement part or to inquire about parts not listed in the parts list, address order or inquiry either to your authorized Kepco Sales Representative or to:

KEPCO, INC.
131–38 Sanford Avenue
Flushing, N.Y. 11352

6-5 Specify the following information for each part:

a) Model and complete serial number of instrument.

b) Kepco part number.

c) Circuit reference designator.

d) Description.

6-6 To order a part not listed in the parts list, give a complete description and include its function and location.

NOTE: KEPCO DOES NOT STOCK OR SELL COMPLETE POWER SUPPLY SUBASSEMBLIES AS DESCRIBED HERE AND ELSEWHERE IN THIS INSTRUCTION MANUAL. SOME OF THE REASONS ARE LISTED BELOW:

1) Replacement of a complete subassembly is a comparatively rare necessity.

2) Kepco's subassemblies are readily serviceable, since most of them are of the "plug-in" type.

3) All active components are socket mounted, making replacement extremely easy.

4) The nature of a closed-loop power supply system requires that subassembly replacement is followed by careful measurement of the total power supply performance. In addition, depending on the function of the subassembly, extensive alignment may be required to restore power supply performance to specified values.

IF REPAIRS INVOLVING SUBASSEMBLY REPLACEMENTS ARE REQUIRED, PLEASE CONSULT YOUR LOCAL KEPCO REPRESENTATIVE OR THE KEPCO SALES ENGINEERING DEPARTMENT IN FLUSHING, NEW YORK, N.Y.

ABBREVIATIONS USED IN KEPCO PARTS LISTS

A) Reference Designators:

A = Assembly
B = Blower (Fan)
C = Capacitor
CB = Circuit Breaker
CR = Diode
DS = Device, Signaling (Lamp)
F = Fuse
FX = Fuse Holder
IC = Integrated Circuit
J = Jack
K = Relay
L = Inductor
LC = Light-Coupled Device
M = Meter
P = Plug
Q = Transistor
R = Resistor
S = Switch
T = Transformer
TB = Terminal Block
V = Vacuum Tube
X = Socket

B) Description Abbreviations

A = Ampere
AC = Alternating Current
AMP = Amplifier
AX = Axial
CAP. = Capacitor
CER = Ceramic
CT = Center-Tap
°C = Degree Centigrade
FXD = Fixed
Ge = Germanium
H = Henry
Hz = Hertz
IC = Integrated Circuit
K = Kilo (10^3)
m = Milli (10^{-3})
M = Mega
MFR = Manufacturer
MET. = Metal
n = Nano (10^{-9})
NC = Normally Closed
NO = Normally Open
P = Pico (10^{-12})
PC = Printed Circuit
POT = Potentiometer
PIV = Peak Inverse Voltage
p-p = Peak to Peak
ppm = Parts Per Million
PWR = Power
DC = Direct Current
DPDT = Double Pole, Double Throw
DPST = Double Pole, Single Throw
ELECT = Electrolytic
F = Farad
FILM = Polyester Film
FLAM = Flammable
°F = Degree Farenheit
RAD = Radial
RECT = Rectifier
REG = Regulated
RECY = Recovery
RES = Resistor
RMS = Root Mean Square
Si = Silicone
S-End = Single Ended
SPDT = Single Pole, Double Throw
SPST = Single Pole, Single Throw
TAN = Tantalum
TSTR = Transistor
u = Micro (u) (10^{-6})
VAR = Variable
V = Volt
W = Watt
W.W. = Wire Wound

PRINTED CIRCUIT BOARD ASSEMBLY (A1), MODEL CC 15-1.5(M) **Code 12-1671**

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (SEE NOTE)	KEPCO PART NO.
A_M,A_V	2	I.C. Amplifier 8 Pin, Dip	Texas Instrument SN 72741P	250-0025
C1	1	Cap.,Elect.,Axial Leads 75 μF, 50V	Sprague Type 30D	117-0646
C2	1	Cap.,Elect.,Axial Leads 290 μF, 12V	Sprague Type 30D	117-0647
C3A&B	2	Cap.,Elect.,Axial Leads 825 μF, 40V	General Electric Type 43F	117-0430
C4	1	Capacitor,Mylar,Axial Leads 0.1 μF, 200V, 20%	Sprague Type 192P	117-0186
C5	1	Capacitor,Mylar,Axial leads 0.3 μF, 200V, 10%	TRW X663F	117-0509
C6	1	Capacitor,Ceramic,Disc. 200 pF, 1 K V, 10%	Ratio Materials Corp. Type JF	117-0571
CR1,2,4,15,16, 17,19,20,22	9	Rectifier,Silicon,Axial Leads	Semicon SM-110	124-0133
CR3,11,12,13,14	5	Zener Diode,Axial Leads 6.5V ±5%	Transitron SV125	121-0028
CR5,6,7,8, 9,10,18	7	Rectifier,Silicon,Axial Leads	Semicon S-5A1	124-0347
CR21	1	Zener Diode,Axial Leads 5.6 to 6.5V	International Resistance 1N821	121-0041
CR23	1	Zener Diode 3.3V ±5%	Transitron 1N796A	121-0060
F1	1	Fuse,Slow Blow 0.8A	Bussman MDL-8/10	141-0027
Q1,2,5	3	Transistor,Silicon,NPN	Westinghouse 119-0094	119-0094
Q3,4	2	Transistor,Silicon,NPN	Fairchild 2N5133	119-0093
R1	1	Resistor,Fixed,Precision,M.F. 221 ohm, 1/4 W, 1%	IRC CEA Type	115-2311
R2	1	Resistor,Fixed,M.G. 82 K ohm, 1/4 W, 5%	IRC RG 1/4	115-2012
R3	1	Resistor,Fixed,Molded 3.9 K ohm, 1/2 W, 5%	Allen Bradley EB3925	115-0808
R4	1	Resistor,Fixed,Molded 1 K ohm, 1/2 W, 10%	Allen Bradley EB1021	115-0547
R5	1	Resistor,Fixed,Molded 560 ohm, 1/2 W, 10%	Allen Bradley EB5611	115-0451
R6,7	2	Resistor,Fixed,Power,Axial 0.5 ohm, 3 W, 5%	Tepro TS-3C	115-0504
R8	1	Resistor,Fixed,Molded 120 ohm, 1/4 W, 10%	IRC Type GBT 1/4	115-2232

NOTE:
REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

PRINTED CIRCUIT BOARD ASSEMBLY (A1), MODEL CC 15–1.5(M) **Code 12-1671**

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (SEE NOTE)	KEPCO PART NO.
R9	1	Resistor,Fixed,Power,Axial 1.5 K ohm, 3 W, 5%	Tepro TS-3C	115-1189
R10	1	Resistor,Fixed,M.G. 39 ohm, 1/4 W, 5%	IRC RG 1/4	115-2307
R11,12	2	Resistor,Fixed,Power,Axial 750 ohm, 3 W, 5%	Tepro TS-3C	115-0885
R13	1	Resistor,Fixed,Molded 47 K ohm, 1/4 W, 10%	IRC GBT 1/4	115-2237
R14	1	Resistor,Fixed,M.G. 6.2 K ohm, 1/4 W, 5%	IRC RG 1/4	115-2258
R15	1	Resistor,Variable,Cermet 2 K ohm, 0.75 W, 20%	Helipot 78PR2K	115-2032
R16	1	Resistor,Fixed,Power,Axial 0.333 ohm, 3 W, 3%	Tepro TS3WN1	115-1881
R17	1	Resistor,Fixed,Molded 10 K ohm, 1/4 W, 10%	IRC GBT 1/4	115-2211
R18,23	2	Resistor,Variable,Cermet 10 K ohm, 3/4 W, 20%	Helipot 78PR10K	115-2085
R19	1	Resistor,Variable,Cermet 500 ohm, 0.75 W, 30%	Helipot 78PR500	115-2063
R20,30	2	Resistor,Fixed,Molded 560 ohm, 1/4 W, 10%	IRC GBT 1/4	115-2210
R21	1	Resistor,Fixed,M.G. 1.5 K ohm, 1/4 W, 10%	IRC GBT 1/4	115-2229
R22	1	Resistor,Fixed,Precision,M.F. 57.6 K ohm, 1 W, 1%	IRC CEC Type	115-2143
R24	1	Resistor,Fixed,Precision,M.F 750 ohm, 1/4 W, 1%	IRC CEA Type	115-2259
R25	1	Resistor,Fixed,Precision,M.F. 10 K ohm, 1/4 W, 1%	IRC CEA Type	115-2174
R26	1	Resistor,Fixed,Precision 0.667 ohm, 50 W, 1%	Tepro TM50W	115-1385
R27	1	Resistor,Fixed,Precision 6 ohm, 5 W, 1%	Tepro TSK-5W	115-2243
R28	1	Resistor,Fixed,Precision,WW 5.9 ohm, 1 W, 1%	Tepro TS1W	115-2341
R29	1	Resistor,Fixed,Precision,M.F. 1 K ohm, 1/4 W 1%	IRC CEA Type	115-2180

NOTE:

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

MAIN CHASSIS ASSEMBLY, MODEL CC 15–1.5(M) **Code 12-1671**

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (SEE NOTE)	KEPCO PART NO.
FRONT PANEL SECTION CONTAINS:				
M101	1	Meter 0–1.5A/0–0.15A d-c	Ammon Instr. Type FM-1	135-0461
M102	1	Meter 0–15V	Ammon Instr. Type FM-1	135-0410
R101	1	Resistor,Variable,WW 10 K ohm, 1.5 W, 5%	IRC Type 5000	115-2336
S101	1	Switch	Stackpole SS-72-1	127-0254
Q201,202	2	Transistor,NPN	Westinghouse 119-0082	119-0082
SDS201	1	Switch & Pilot Light	Lee Craft Mfg. 51XP11	127-0229
T201	1	Transformer	Kepco Magnetics 100-1768	100-1768

NOTE:

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

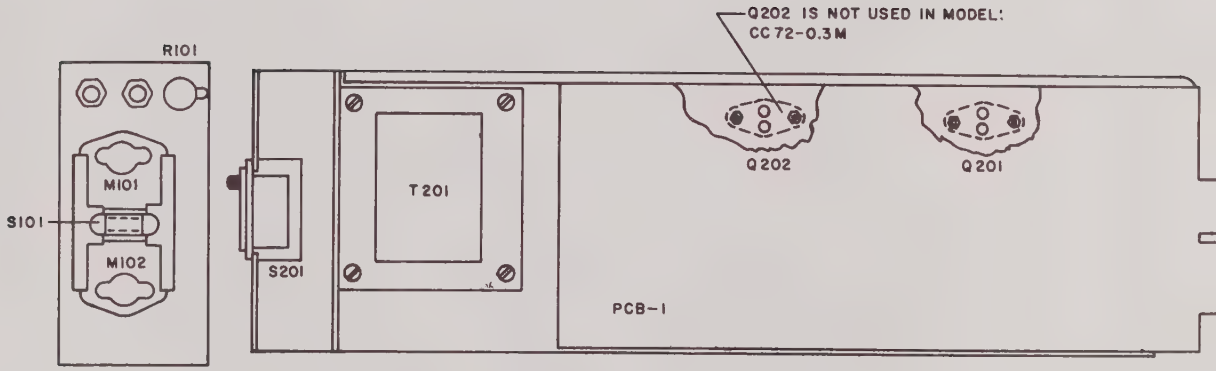
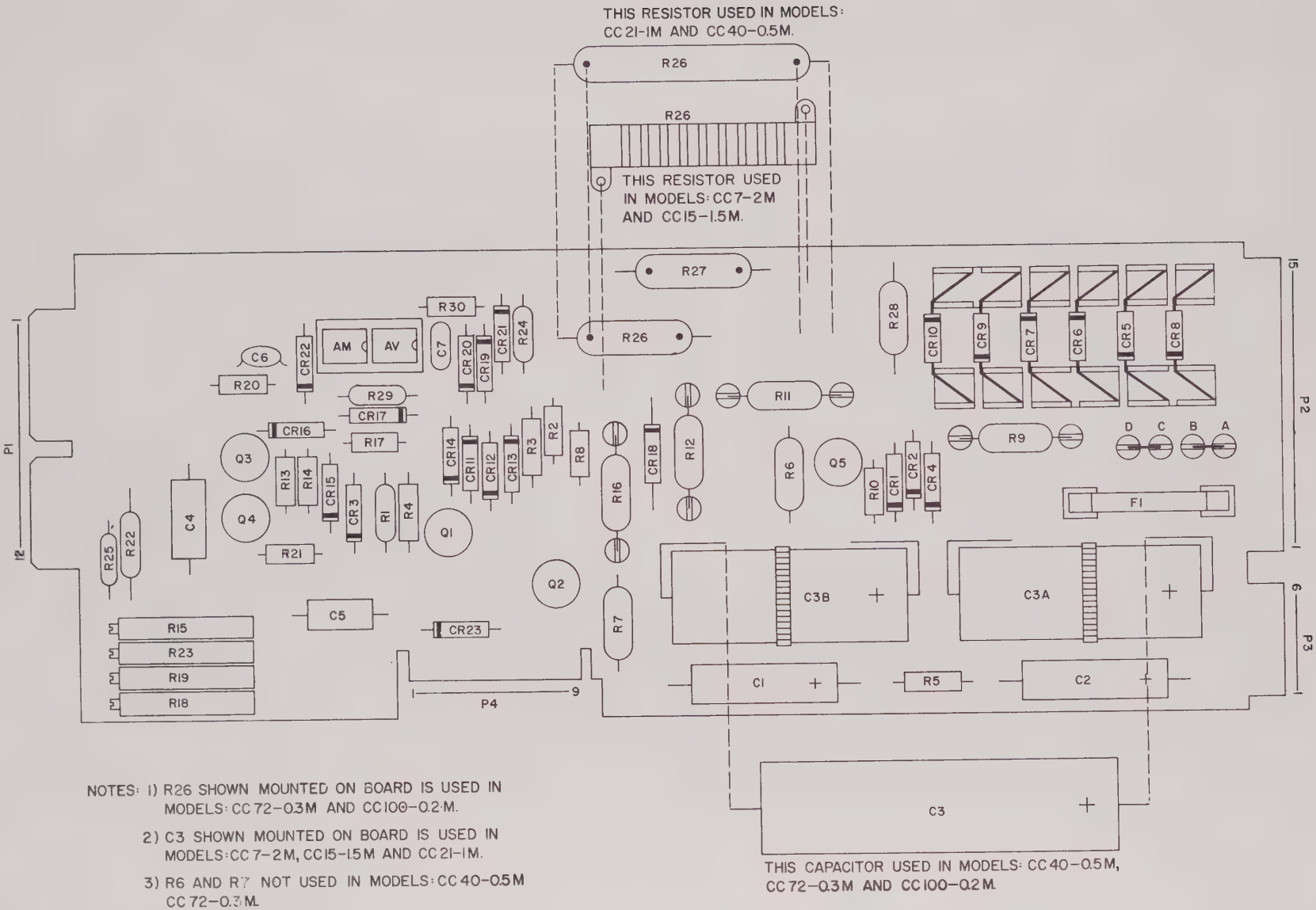


FIG. 6-1 CHASSIS COMPONENT LOCATION.



NOTES: 1) R26 SHOWN MOUNTED ON BOARD IS USED IN MODELS: CC 72-0.3M AND CC 100-0.2M.

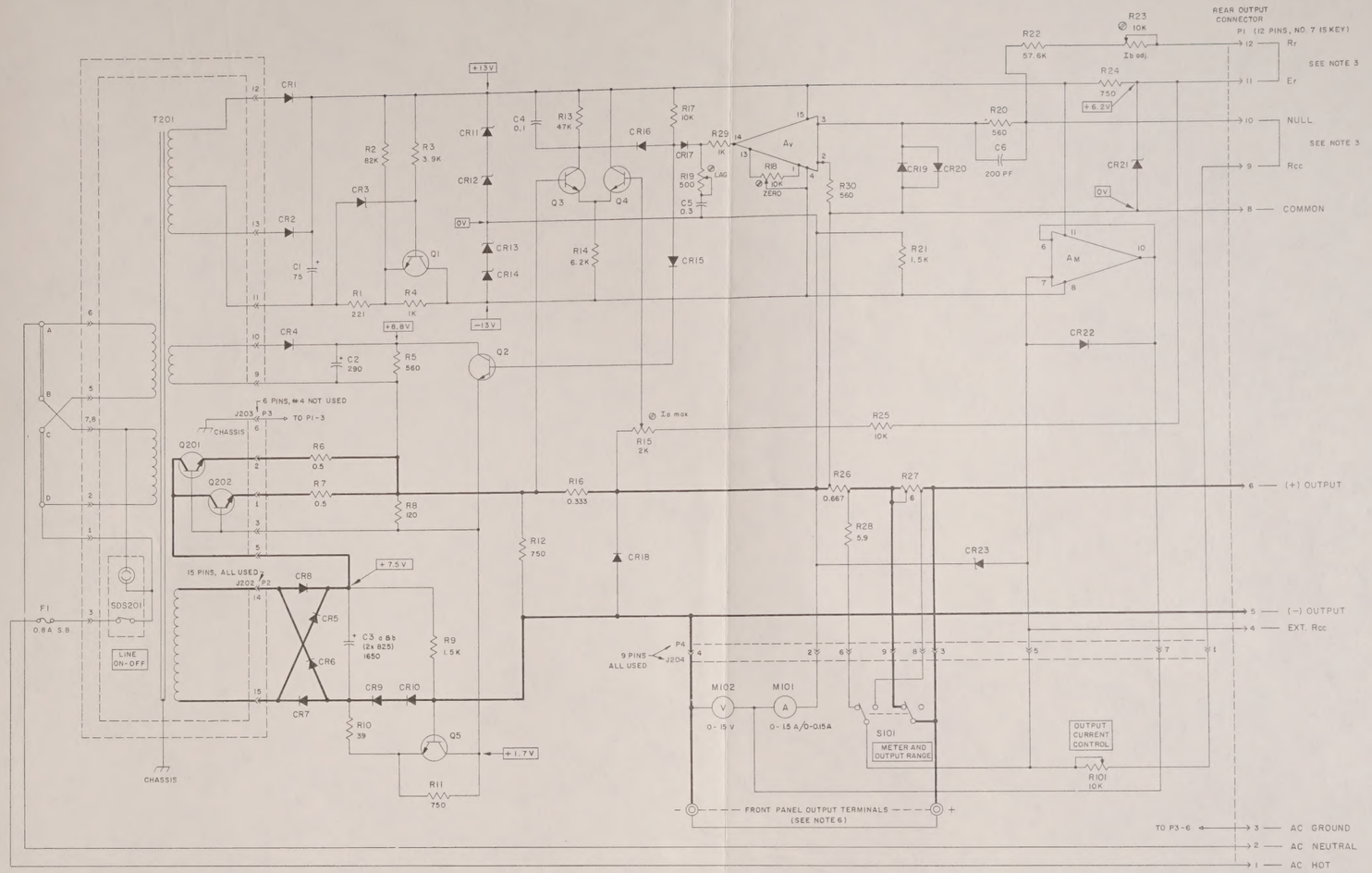
2) C3 SHOWN MOUNTED ON BOARD IS USED IN MODELS: CC 7-2M, CC 15-1.5M AND CC 21-1M.

3) R6 AND R7 NOT USED IN MODELS: CC 40-0.5M CC 72-0.3M.

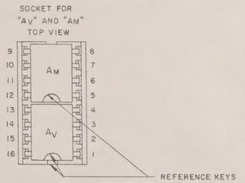
4) C7 USED ONLY IN MODELS: CC 72-0.3M AND CC 100-0.2M.

THIS CAPACITOR USED IN MODELS: CC 40-0.5M, CC 72-0.3M AND CC 100-0.2M.

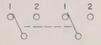
FIG. 6-2 PCB #1 (A1) COMPONENT LOCATION.



NOTES:
1. RESISTOR VALUES IN OHMS, K=1000.
2. CAPACITOR VALUES IN MICROFARADS, UNLESS INDICATED OTHERWISE.
3. LINKS ON P1 MUST BE CLOSED FOR STANDARD OPERATION.
4. CONDITIONS FOR LISTED VOLTAGE READINGS
   A) LINE AT 115 V AC, 60HZ
   B) METER: 20K OHMS PER VOLT
   C) REFERENCE POINT: COMMON.
   D) MAXIMUM OUTPUT CURRENT, FULL COMPLIANCE VOLTAGE
   E) READINGS SUBJECT TO NORMAL COMPONENT TOLERANCES
5. MAIN TRANSFORMER SHOWN FOR 115 V AC OPERATION.
6. EXTERNAL SHORTING LINK, REMOVE FOR STANDARD OPERATION.
7. COMPONENT NOS 1-99 ON PCB #1 (A1) AMPLIFIER BOARD.
8. COMPONENT NOS 101-199 ON FRONT PANEL.
9. COMPONENT NOS 201-299 ON MAIN CHASSIS.



LEGEND S101
POS.1 Io max.
POS.2 Io max/10



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Data subject to change without notice.
PATENT NOTICE: Applicable Patent Nos. ® will be supplied on request.

FIG. 6-3 MAIN SCHEMATIC, MODEL CC 15-1.5(M).

EM11524-12-1671

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